REMARKS

Claims 1 through 29 are pending in the application. Claims 1-29 are rejected.

Claims 1-29 are amended. Claims 30-31 are newly added.

Applicants submit that the amendments are fully supported by the patent specification and do not add any new matter.

Support for the newly added claims (discolored diamonds that are brown) can be found in the specification, including but not limited to the 1st paragraph of the Background of the Invention.

Support for the amended claims, from elevated temperature and pressure to 1500°C and 10 kilobars can be found in the patent specification, "Detailed Description of the Invention," page 15, last paragraph.

Supported for the amended claims 23-27 and 29 for the diamonds to have a high concentration of H3 centers as determined by H3 absorption line at 503 nm can be found in the Examples.

35 U.S.C. § 112 Rejection. The Examiner rejects claims 1-29 under 35 USC 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention.

1) The Examiner indicates that in claims 1, 28, "improve(ing)" is subjective and unclear. Applicants have amended the claims to use the term "change" as suggested by the Examiner.

2) The Examiner indicates that "discolored" is unclear. Applicants respectfully traverse the Examiner's rejection for the reason that "discolored" must be reasonably apprised by a person of ordinary skill in the art of the invention.

MPEP §2173.01 provides that Applicants "can define in the claims what they regard as their invention essentially in whatever terms they choose so long as the terms are not used in ways that are contrary to accepted means in the art." With respect to clarity and precision, the standard set by MPEP §2173.02 is that definiteness of claim language must be analyzed in light of: a) The content of the particular application disclosure; (B) The teachings of the prior art; and (C) The claim interpretation that would be given by one possessing the ordinary level of skill in the pertinent art at the time the invention was made.

Applicants submit that the term "discolored diamond" is commonly understood and accepted by the diamond trade / art to mean diamonds of poor quality, off-colored, less transparent, etc. At site http://www.organizedregistry.com/engagement_ring/create.php, it is taught that: "Color ratings usually range from D to X, with D being a very clear diamond, and X being a very *discolored diamond.*"

At another industry web sites http://www.wikipedia.org/wiki/Diamond, it is disclosed that "80% of the diamonds produced are poorer quality (*discolored*, less transparent) diamonds which are used as industrial diamonds, where their extreme hardness is useful in cutting and grinding otherwise intractable materials (including other diamonds)."

Similarly, at http://www.all-gem-stones.com/se/diamond.html, it is disclosed that: "Only 20 per cent of diamonds are suitable for cutting as gems. *The rest are discolored or contain flaws*. Because of their extreme hardness, diamonds have a number of important industrial applications. They are used in drill bits, glass cutters, masonry saws for shaping building stone, and for cutting other diamonds."

A copy of the screen print-outs of the above-referenced Web sites is attached herewith.

3) The Examiner indicates that in claims 24-27, "fancy" is subjective and unclear. Applicants respectfully traverse the Examiner's rejection for the reason that "fancy" must be reasonably apprised by a person of ordinary skill in the art of the invention.

Applicants respectfully traverse the Examiner's rejection, and ask that the claimed invention be analyzed per standard set by MPEP §2173.02, specifically in light of: a) The content of the particular application disclosure; (B) The teachings of the prior art; and (C) The claim interpretation that would be given by one possessing the ordinary level of skill in the pertinent art at the time the invention was made.

The term "fancy-colored diamonds" is a term in the diamond trade to denote diamonds that display enough of a hue, depth, or nuance of color. The Examiner is respectfully asked to check the site http://www.professionaljeweler.com/archives/articles/1999/feb99/0299dg.html. This is a Web site of the Professional Jeweler magazine, a trade journal directed to 23,000 jewelers in the US, wherein it is defined that: "*A 'fancy' diamond* is a natural diamond of color – such as red, green, purple, violet, orange, blue and pink – and should not be confused with a "fancy cut," which refers to shape. *Fancy colors* vary from faint to intense."

There is also a well-known reference in the trade titled "Fancy Colored Diamonds" by Harvey Harris, published in Lichtenstein by Fancoldi Registered Trust, 1994.

The GIA or the Gemological Institute of America, Inc., the creator of the famous 4C's of diamond value (color, clarity, cut and carat weight) and the most reputable and non-profit trade organization dedicated to grading diamonds, offers a free tutorial to consumers on "How to Buy Diamonds" and "learn the 4 C's of diamonds value" at www.gia.org. In the Glossary section, consumers are invited to click a term to view its definition. Under "fancy colored," GIA has the following definition: "Any naturally colored diamond with a noticeable depth of body color considered to be rare or attractive. Red and green are the rarest fancy colors, followed by purple, violet, orange, blue, and pink. Yellow and greenish yellow diamonds are more common. While white, black, and gray are not, strictly speaking, spectral colors, they are also considered fancies. In the GIA color grading system, *fancy color* grades are described as faint, very light, light, fancy light, fancy, fancy intense, and fancy dark."

The definition or explanation of "fancy-colored" can also be found in a number of print and on-line references of international trade organizations and companies, including the following Web sites (found in Google using the key terms "fancy colored" and diamonds):

http://www.azgem.com/newsletters/newsletter-06-02.html
http://www.giftsofnz.com/possum/pacjewel/diamondsthe4cs.htm
http://www.hagoj.com/acatalog/E_Learn_Diamond.shtml
http://www.diamondbrokersoffl.com/color.htm
http://www.diamond-engagement-rings-guide.com/diamond-dictionary.html

A copy of the screen print-outs of the above-referenced Web sites is attached herewith.

4) In claim 1c, the Examiner indicates that the graphite-stable region encompasses room temperature and atmospheric pressure, therefore "elevated" is unclear as to the basis for comparison. Applicants have amended the claims to further qualify "elevated pressure" and "elevated temperature" to a pressure of at least 10 kilobars, and a temperature of at least 1500°C.

5) With respect to claim 3, the Examiner indicates that "with platelets" is unclear as how the platelets relate to the diamond structure. Applicants respectfully traverse the Examiner's rejection, and again ask that the claimed invention be analyzed per standard set by MPEP §2173.02.

The term "platelet" is a term known in art related to diamond and their structure, specifically relating to "defects" within diamond. Attached is a scientific report from "The 1997-1998 Synchrotron Radiation Source Report" published by CRLC Daresbury Laboratory, by Moore et al., titled "Reciprocal Space Mapping of Planar Defects in Diamond" wherein planar defects in diamond in the form of "platelets" are discussed. This article can also be found at the link http://srs.dl.ac.uk/Annual_Reports/AnRep97_98/Annexe/296_Moore.pdf.

There are also well-known references about platelets in diamond, including the articles titled 1) "Theory of Nitrogen and Platelets in Diamond" by Briddon et al., in Materials Science Forum 83-7, 457-462, 1991; and "Small Aggregates of Interstitials and Models for Platelets in Diamond" in Journal of Physics: Condensed Matter 12(49), 10257-10261 (2000) by Goss et al.

In addition to the above references, the definition for or explanation of "platelets" can also be found in a number of print and on-line references of international / scientific sources, including but not limited the following Web sites (found in Google using the key terms platelets and diamonds):

http://www.ioffe.rssi.ru/SVA/NSM/Semicond/Diamond/bandstr.html
http://www.scirus.com/search_simple/?frm=narrow&query_1=(platelets)+AND+(%22interstitials%22)
http://web.utk.edu/~pgi/diamond/page3.html

A copy of the screen print-outs of the above-referenced Web sites is attached herewith.

6) The Examiner indicates that the recitation of colors in the claimed invention is potentially unclear in view of colorblindness, etc. The Examiner correctly points out that claims

24 and 25 are duplicates.

In claims 7-9 and 24-27, the claimed invention is directed to recovered diamond of different colors, including neon yellow-green, yellowish green, and greenish yellow. Applicants have canceled duplicate claim 25.

Applicants again respectfully traverse the Examiner's rejection for the reason that the claimed invention should be analyzed per MPEP §2173.02 standard.

Applicants respectfully submit that the recitation of colors in the claimed invention is not subjective / unclear, and that the colors can be quantified / measured via spectro technology by one possessing the ordinary level of skill in the pertinent art of diamond / gemstone. It is well-known in the diamond / gemstone art to qualify colors scientifically by using the CIELAB diagram. CIE is the Commission Internationale de l'Eclairage, the international body responsible for recommendations for colorimetry and photometry. The CIELAB (L*a*b) color space refers to the color diagram developed by CIE in 1976, and also disclosed by Applicants in the Background of the Invention page 7.

Attached is a paper titled "CIE Fundamentals for Color Measurements" by Yoshi Ohno of the National Institute of Standards and Technology, as presented at the IST&T NIP16 Conference in October 2000, on the CIELAB diagram wherein the three attributes of color (i.e., hue, chroma, and lightness) are expressed in a three dimensional space or diagram. Applicants respectfully direct the Examiner's attention to Figure 4 in the paper wherein the yellow green colors, or specifically the yellowish / greenish colors being defined to be the continuum of colors in the upper left (northwest) quadrant of the LAB color space diagram. It should also be noted that in the CIELAB diagram, the hue angle h_{ab} is defined as $h_{ab} = \tan^{-1} (b^* / a^*)$ and the chroma is defined as $c = (a^{*2} + b^{*2})^{1/2}$.

A Google search using the key words "CIELAB color diagram 'yellowish green'" or "CIELAB color diagram "greenish yellow") yield a number of references discussing the CIELAB color diagram and the reproduction / identification of colors, including the colors in the claimed invention:

http://www.pcimag.com/CDA/ArticleInformation/features/BNP__Features__Item/0,1846,91729,00.html
http://cit.dixie.edu/vt/reading/gamuts.asp

A copy of the screen print-outs of the above-referenced Web sites is attached herewith.

In view of the foregoing reasons, Applicant respectfully requests reconsideration and withdrawal of the rejection of Claims 1-29 under 35 U.S.C. § 112, second paragraph.

35 U.S.C. § 102(b) / 35 U.S.C. § 103(a) rejection – Satoh et al. US Pat. No. 4,959,201. The Examiner rejects claims 23-27 and 29 under 35 USC 102(b) as anticipated by, or in the alternative, under 35 USC 103(a) as being obvious over Satoh et al. The Examiner indicates that Satoh describes a yellow diamond whose color is altered to green, and that the burden of proof is shifted to the applicant to establish that the claimed invention is patentably distinct. Applicants respectfully traverse the Examiner's rejection.

Satoh discloses a green diamond "suitable for ornamental purposes" having "substantially only H2 centers … and show a brilliant green" (Satoh, column 4, lines 3-5), with the H2 centers being absorptive at 650-1000 nm and with the absorption peak being at 800 nm. The "feed" to produce the Satoh green diamond is a bright yellow type Ib natural or artificial diamond.

Applicants have amended claims 23-27 and 29 to include the limitation of a high concentration of H3 centers as determined by H3 absorption line at 503 nm.

To anticipate a claim, a reference must disclose each and every element of the claim. *Lewmar Marine v. Varient Inc.*, 3 U.S.P.Q.2d 1766 (Fed. Cir. 1987). For an obviousness rejection to be proper, the Examiner must meet the burden of establishing a prima facie case of obviousness. *In re Fine*, 5 U.S.P.Q.2d 1596, 1598 (Fed. Cir. 1988). Establishing a prima facie case of obviousness requires that all elements of the invention be disclosed in the prior art. *In re Wilson*, 165 U.S.P.Q. 494, 496 (C.C.P.A 1970).

Satoh does not teach Applicants' limitation of a high concentration of H3 centers as determined by H3 absorption line at 503 nm. As Satoh does not expressly or inherently teach or suggest all of the limitations in Applicant's amended claims 23-27 and 29, Satoh cannot anticipate amended claims 23-27 and 29, nor is Satoh sufficient to establish a prima facie obviousness against claims 23-27 and 29.

Applicant respectfully requests the reconsideration and withdrawal of the rejection of claims 23-27 and 29 under 35 U.S.C. § 102(b) or § 103(a) over Satoh.

35 U.S.C. § 102(b) / 35 U.S.C. § 103(a) rejection - Harlow Book on The Nature of Diamonds. The Examiner rejects claims 23-27 and 29 under 35 USC 102(b) as anticipated by, or in the alternative, under 35 USC 103(a) as being obvious over the Harlow reference, "The Nature of Diamonds" as published by Cambridge University Press in 1998. The Harlow book has a chapter on "The Nature of Color in Diamonds" by Emmanuel Fritsch (pp. 23-47). The Examiner indicates that color green-yellow diamonds are depicted on page 24 of the Harlow book, and that the Harlow diamonds are deemed to be the same as the claimed invention although Harlow does not teach / disclose the claimed process.

Figure 1 on page 24 of the Harlow book is a picture of the diamonds in the Aurora Collection, the world's most famous "natural" colored diamond collection that has been on display at the American Museum of Natural History in New York since 1989. Applicants respectfully traverse the Examiner's rejection of the claimed invention over the Harlow reference.

Applicants fully understand that as a practical matter, "the Patent Office is not equipped to manufacture products by the myriad of processes put before it and then obtain prior art products and make physical comparisons therewith." It is the Applicants' burden to establish that the diamond as in claims 23-27 and 29 are distinguishable from the natural colored diamonds in the Harlow reference.

Applicants submit that the product-by-process of the present invention is distinguishable by one of ordinary skill in the art in various ways, including but not limited to the followings:

1) US Patent No. 6,377,340, which discloses a "method of detection of natural diamonds that have been processed at high pressure and high temperatures," i.e., that a product made by the process of the present invention. This reference discloses an equipment comprising a spectrometer connected to a computer so the photoluminescent spectrum of the illuminated diamond is recorded. In this reference, "[T]he spectrum is examined for a line at 2.53 eV, which is believed to be related to the H4 line that is an emission line for a nitrogen B Center plus a vacancy. If the 2.53 eV line is present in the spectrum, the diamond 16 can be characterized as not having been through an HPHT process. If the 2.53 eV line is absent, the diamond has either been processed by an HPHT process, or contains an unusually low amount of nitrogen, such as less than 10 parts per billion of nitrogen. It is determined that the method, as embodied by the invention, provides the step of determining that the diamond was processed under HPHT conditions with up to about a 95% probability."

2) Methods / Equipment disclosed by DeBeers, the largest diamond dealer in the world at their Web site http://www.debeersgroup.com/researchDev/rdDTCGem2.asp, wherein it is disclosed that "the fluorescence patterns from high pressure high temperature grown synthetic diamonds differ significantly from the patterns seen from natural diamonds [the Harlow diamonds]" and that an HP/HT diamond can be distinguished from a natural diamond via the use of a DeBeers instrument called DiamondSure / DiamondView.

3) A Wed publication associated with AJM Magazine (the Authority on Jewelry Manufacturing) at http://www.ganoksin.com/borisat/nenam/ajm-diamond-treatments.htm, wherein it is disclosed that "Conclusive identification of HPHT treated diamonds requires low-temperature visible and photoluminescence spectroscopy, techniques normally available only in gemological laboratories. Some visible signs that a colored diamond warrants further investigation include high saturation and darker tones of color; noticeable banded internal graining (in a colorless diamond); the presence of graphitized "feathers"; and altered inclusions with surrounding radial fractures. HPHT treated colored diamonds can also show distinctive fluorescence reactions to long- and short-wave ultraviolet radiation."

4) Detection equipment offered at http://www.gis.net/~adamas/sas2000.html, specifically for a "SAS2000 Spectrophotometer Analysis System" which "has the high optical resolution needed to differentiate most fancy colored diamonds from their naturally colored counterparts [the Harlow diamonds]."

In view that the process of the present invention and the product made therefrom are distinct from the natural diamonds of the Harlow reference, Applicants submit that Harlow cannot anticipate amended claims 23-27 and 29, nor is Harlow sufficient to establish a prima facie obviousness against claims 23-27 and 29

35 U.S.C. § 102(b) / 35 U.S.C. § 103(a) rejection – Strong et al. US Pat. No. 4,124,690. The Examiner rejects claims 23-27 and 29 under 35 USC 102(b) as anticipated by, or in the alternative, under 35 USC 103(a) as being obvious over Strong et al. The Examiner indicates that Strong teaches the existence of yellow / green diamonds, and the Strong diamonds are deemed to be the same as the claimed invention although Strong does not teach / disclose the claimed process. Applicants respectfully traverse the Examiner's rejection.

Strong teaches the conversion of type Ib or mixed type Ib-Ia natural diamond having a "greenish-yellow" color or a "yellow" color as the starting color, to be at least a shade lighter yellow, i.e., for the result to be a diamond having a very pale yellow or a colorless crystal (Strong, column 4, lines 40-50). In the Strong process, type Ib nitrogen is converted to type Ia nitrogen and that the nitrogen is not "being converted to nitrogen of yet another type" (Strong column 8, lines 63).

The claimed invention, on the other hand, is directed to a "brown" diamond selected from type IaB, type IaA/B, type IaA or type Ib with one of A Centers, B Centers, C Centers, or combinations thereof, having the color changed and having the nitrogen being converted to a high concentration of H3 centers as determined by H3 absorption line at 503 nm.

Strong does not teach Applicants' limitation of a diamond having a high concentration of H3 centers as determined by H3 absorption line at 503 nm. As Strong does not expressly or inherently teach or suggest all of the limitations in Applicant's amended claims 23-27 and 29, Strong cannot anticipate amended claims 23-27 and 29, nor is Strong sufficient to establish a prima facie obviousness against claims 23-27 and 29.

35 U.S.C. § 103(a) rejection – Strong et al. US Pat. No. 4,124,690 / Wentorf, Jr. US Pat. No. 3,609,818. The Examiner rejects claims 1-29 as being unpatentable over Strong et al., alone or taken with Wentorf. Specifically, the Examiner indicates that Strong teaches annealing of Type 1b diamonds at elevated T and P, resulting in a change of color, and that the use of the pill in the claimed invention is obvious. The Examiner further asserts that although Strong does not teach or form a pill, Wentorf teaches the use of talc / salt as a pressure transmitting medium. The Examiner concludes that the use of talc in the Strong process is obvious to attain uniform pressure on the treated diamonds, and that treating diamonds having a particular type / N content / platelets is an obvious expedient to make a more valuable material.

Applicants respectfully traverse the Examiner's rejection for the reason that Strong teaches away from the present invention. In the Strong reference, the objective is to change the color of diamond crystals from type Ib, i.e., "a deep golden yellow to a pale yellow with the deep golden yellow indicating substantially more type Ib dissolved nitrogen than the pale yellow" (Strong column 2, lines 53-55), to a type Ia with "*the result [being] a very pale yellow and / or a colorless crystal*" (Strong column 6, lines 47-48). As the result of the Strong process, "at least a portion of the [type Ib or mixed type Ib-Ia] crystal undergoes some change in color or shade, ...*at least a shade lighter yellow*..." (emphasis added).

On the other hand in the method of the present invention, discolored diamond of a Type IaB, Type IaA/B , Type IaA or Type Ib diamond, and having at least one of A Centers, B Centers, and C Centers becomes one of yellowish-green, greenish-yellow and neon yellow-green. Strong does not teach / suggest the conversion of a discolored diamond into one of a rich hue in color, i.e., yellowish-green, greenish-yellow and neon yellow-green. Strong essentially teaches away from the present invention in the quest for a lighter and / or colorless diamond.

With respect to Wentorf, this reference discloses a high pressure, high temperature apparatus for the preparation of stronger, thicker diamond compacts, wherein a mass of diamond crystals is infused with a molten catalyst material. Applicants respectfully submit that Wentorf does not remedy Strong's failure to teach / suggest the claimed invention of changing the color

of a discolored diamond of a type IaB, type IaA/B, type IaA or type Ib with one of A Centers, B Centers, C Center, or combinations thereof. For this reason, a prima facie case of obviousness against Applicants claims 1-29 has not been established.

35 U.S.C. § 103(a) rejection – Cannon US Pat. No. 3,134,739. The Examiner rejects claims 1-16, 19-29 as being unpatentable over Cannon. Specifically, the Examiner indicates that Cannon teaches placing colored diamonds and graphite filler into a press and treating under HP/HT, for a resulting change in color.

Applicants respectfully traverse the Examiner's rejection. Cannon relates to a method of whitening diamonds and changing the electrical characteristics of diamonds. Cannon relates to an electrically conductive diamond containing aluminum atoms introduced through a diffusion process. See col. 1, lines 10-14.

Attached herewith is an affidavit by Dr. Suresh Vagarali's which previously was submitted to the USPTO in the parent application Serial No. 09/162,206, wherein Dr. Vagarali's establishes that a diamond will not change color when practiced in accordance with the methods taught in Cannon. As stated in this declaration, Dr. Vagarali conducted four experiments to evaluate the effect of pressure and temperature for changing the color of diamonds as disclosed in Cannon. The experiments were run to determine the veracity of the Cannon invention as defined by the statement, "At high pressures and temperatures, diamonds grown become more clear and white, but aluminum diffusion provides a more marked and contrasting change to colors." (Cannon, col. 6 line 73 to col. 7, line 1).

From the experiments, it is clear that Cannon does not teach or suggest a method for changing the color of a diamond, as recited in Applicants' claimed invention. Therefore, for the reasons of record and in view of Dr. Vagarali's declaration, Cannon would not have taught or suggested Applicants' claimed invention to one of ordinary skill.

CONCLUSION. In view of the foregoing amendments and remarks, Applicants respectfully request reconsideration of this application and the timely allowance of the pending claims.

Respectfully submitted,

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"Create an Engagement Ring with the Perfect Diamond!" --or the best one you can afford, anyway.

part 3 of 5 of
"A Guy's Guide to Building an Engagement Ring"
(1) (2) (3) (4) (5)

"This [page] is brought to you by the letter 'C'"
-- Sesame Street

Cut, Color, Clarity, Carat and Cost. The 5 Cs. Make sure you know about the 5 Cs **before you shop for your diamond.** Let's look at each of the 5 Cs.

Create Engagement Ring Brilliance: CUT

When someone tells you to pay attention to the cut of the diamond, this is good advice. However...

...when someone tells you to pay attention to the cut of the diamond, **this can mean two things**:

- **The overall shape.** Is it round? Pear shaped? Princess cut?
- **The quality of the cut.** What are the depth and dimensions of the stone? (This will affect how brilliant the diamond looks)

Let's look at each of these meanings of 'cut'.

a. **"CUT" as Shape:** A good diamond dealer will carry all of the following shapes: round, princess (square), emerald (rectangular), radiant, oval, pear (or teardrop), marquise (football shaped) and heart shaped.

You will have a chance to see each of these shapes when we finally get to the ring-building tutorial on the next page.

Round is safe. If you don't know what your girlfriend would like, and you'd like to surprise her, get a round cut diamond. Even if she'd like another shape, you can exchange it. And if you don't want to exchange it, you can always find a way to use a round diamond (e.g. in a pendant, in a second ring, etc).

On the other hand, if you know that she'd like a heart-shaped stone, go for it. I can't really tell you which shape is best. I'll leave that to your own discretion. What's more important is that you understand the

Relationship Questions

Couple Questions

Relationship Test

Relationship Questions

second meaning for "cut".

b **"CUT" as Quality and Depth.** Some diamonds are cut so poorly that nearly all the light that strikes them goes straight through the diamond. Others are cut so well, that almost every photon comes right back at you. (CAUTION: If you are an evil genius, don't shoot laser beams at someone with a large, well-cut diamond!).

Poorly cut diamonds are very dull looking. Very well cut diamonds shine like the sun. Of course the more brilliant the diamond is, the more you will pay for it. But cut is not a place to compromise.

You will usually be given a choice of cut qualities, ranging from poor to ideal. (Actually the better stores won't even sell you a poorly cut diamond. They usually offer you a range from good to ideal.)

I would recommend getting **nothing less than a GOOD cut.** I know that some of you are on a budget (as I was when I bought my wife's engagement ring), but if you have to compromise, compromise on clarity, color and size (carat) before you compromise too much on the cut. A brilliant half carat diamond is much better than a super-dull one carat diamond.

Create a Clean Engagement Ring: COLOR

Most of the quality merchants will not sell diamonds with inferior color.

Color ratings usually range from D to X, with D being a very clear diamond, and X being a very discolored diamond.

A discolored diamond will absorb light, and this means that less light will reflect back to your eye.

Any diamond rated L or better will look perfectly clear to the untrained naked eye -- if it is isolated. But you will notice some difference between a D and an L if they are side by side. The D will be more brilliant, and you may actually detect a slight degree of discoloration in the L. But this is difficult to detect without a perfect prototype to compare it to.

If you must compromise in order to afford a decent diamond, it is better to compromise some on color than to compromise on cut. But only compromise up to a point. I wouldn't recommend you go below L.

Create a Pure Engagement Ring: CLARITY

A diamond is perfectly clear if it has no impurities in it. Now impurities come in two important kinds. Those that can be seen with the naked eye, and those that can't.

Here is how experts rate the clarity of a diamond:

FL - flawless: There are no flaws inside the diamond (such as specks), and the diamond has been finished perfectly, so that there are no flaws

on the exterior of the diamond either.

IF --Internally Flawless: There are no flaws on the inside of the diamond. However, the diamond has been left with a rough finish. This can usually be fixed, leaving you with a perfect diamond. But there is some cost involved, and some risk of workmanship error if you choose to pursue this.

VVS (1 & 2) -- Very, Very Slightly flawed (or "included"): Some specks can just barely be made out under 10x magnification.

VS (1 & 2) -- Very Slightly flawed: Cannot see inclusions (flaws) without magnification.

SI (1 & 2) -- Slightly Included (flawed): Easy to see inclusions with magnification. Still very difficult to see with unaided eye.

Now here is where I can save you a ton of money! Unless your girlfriend has a bunch of friends who go around with eyepieces with 10X magnification, go with a VS diamond. A flawless diamond will usually run right around 30% more, and **you can't tell the difference!**

All else equal, a well-cut VS diamond will sparkle just as much as a well-cut FL diamond--at least you probably can't tell the difference.

That's why I say, if you have to compromise, compromise on color and clarity before you compromise on cut.

Create Engagement Ring Magnificence: CARAT

"So how big is yours?" Guys aren't the only ones who ask this question.

OK, I've never actually had a guy ask me this question, and I'd probably deck him if he did.

The point is that girls do ask this question. OK, girls don't actually ask this question either. But they do look and try to figure out how big it is (I'd probably deck a guy for that, too).

Girls have all kinds of ways of trying to figure out how big a friend's new diamond is. For instance, they can ask sneaky questions. Or they can tell a story about their friend who got a 0.6 carat stone, which causes your girlfriend to offer a comparison. And so on.

Here's the bottom line: **Size Matters!** Don't let her tell you otherwise. Her friends will ask or otherwise pry. And **her self-esteem** when she is with them **will be affected** by how big that rock is on her finger-- more than you (or even she) would like to think. Get the biggest stone you can afford (but not over 2 carats if you expect her to wear it every day).

But, again, don't go for size at the expense of cut. A well cut half-carat diamond is better--much better--than an poorly cut one carat diamond.

But a well cut one carat diamond is even better!

Create Engagement Ring Value: COST

You've heard the rule of thumb--you should spend 2 months pay for the diamond. That is **very cheesy advice** in my book.

What if you make $1,000 a month? Well, you'd better hope she has an income, too, in that case. Could you afford a $2000 ring? Probably not. (But you probably should be asking yourself if you're really ready to get married in this case, too. Maybe you should wait until you get a better job. But then again, who am I to interfere with true love?).

What if you make $30,000 a month. Do you need to spend $60,000 on a ring? Will she be able to lift her hand if you do?

I can't really say. So much depends on what your lady is like, AND, even more importantly, on **what her friends are like.** If she's in the jet set, you'd better spend at least ten grand, or she'll be embarrassed. If you are both from lower-middle class backgrounds, she might be the envy of her friends with a $1,500 ring.

You don't have to make her the envy of her friends. But you'd better not embarrass her either.

Well, that's all for this lesson. Just remember the 5 Cs of diamonds: Cut, Color, Clarity, Carat, and Cost. And if you don't have these down just yet, don't worry. I have prepared for you a **step-by-step tutorial on the next page.**

Now let's put all of this knowledge into action and go build an engagement ring with a great ring building tool.

But wait! There is one other C you should know about--**Cubic Zirconium.** Cubic zirconium is a synthetic material that looks very very much like diamond. In fact, if the CZ is made well, you shouldn't be able to tell the difference.

I'm sure you would never buy CZ on purpose (if you're at all tempted, please read the P.S.), but you should know that diamond fraud is possible--especially if you deal with someone without an established reputation. That's why some dealers offer a **Certificate** to indicate an expert appraisal of quality. These are definitely reassuring. However, ...

...after you buy your diamond, it is always a good idea to get your diamond looked at by an independent professional appraiser. She can help you make sure you don't get sold a piece of junk for a pretty penny.

P.S. For Cheapskates

Of course some of you will be tempted to buy Cubic Zirconium **on purpose.** Shame on you! But if you insist on exploring this option, you really should know about the 4 Cs

of Cubic Zirconium,.

Now for a diamond the 5 Cs are all about the features of the diamond.

But for cubic zirconium the 4 Cs are all about things YOU have to have. If you want to buy a CZ engagement ring, check to make sure you have the following:

1. Cost Consciousness (i.e., cheapskateotiousness): If you buy CZ on purpose, you're probably comfortable with the nickname "Scrooge."

In fact you probably thought Dickens' "A Christmas Carol" had a tragic ending. You probably lamented Scrooge's transformation as he went from a highly virtuous penny pincher to a sorry chap who foolishly spent good money on others.

2. Cleverness. How clever are you? You'd better be very clever if you're going to get your girlfriend a cubic zirconium engagement ring.

I mean what are you going to tell her?

You could lie to her and tell her it's a diamond, and then use your cleverness to constantly come up with ways to keep her from finding out the truth.

You could tell her the truth and tell her it's cubic zirconium, and then use your cleverness to constantly come up with ways to make it up to her for the rest of your married lives.

Or you can use your cleverness to come up with a third option. Personally, I'm stumped. But I'm sure you can think of something, you clever guy.

3. Clear Conscience. Do you have a clear conscience about buying cubic zirconium? If you answer yes, then you should go ahead. But you should also know that there's a good chance that your conscience isn't working properly. But that's good. It will save you a lot of money!

If you do have a properly working conscience, don't buy cubic zirconium. Go buy a diamond instead. If you mix a properly working conscience with cubic zirconium you get constant compunction (also known as a nagging sense of guilt).

4. Comfortable Couch. Finally, if you buy cubic zirconium, on purpose, you'd better make sure you have a comfortable couch. A nice leather couch would be good. **Don't skimp on quality,** you'll be sleeping there a lot!

But I can hear you mumbling, "A comfortable leather couch can easily run me more than a thousand dollars."

True.

Here's my advice: Don't buy a new leather couch. Keep your old futon, and use the money you save toward a nice diamond. A respectable engagement ring will make your Significant Other very happy, and will probably ensure that you're always welcome in her nice comfortable bed ;)

Now, don't get me wrong. I know that you're really a very nice guy. And I know that a really nice diamond can cost you more than you can afford. I'm on your side here, and will try to show you in part 4 how to start with your ideal ring (which might cost more than you can afford) and back the quality off just a little at a time on the different quality dimensions until you arrive at a ring that you are still proud to give her, but which you can afford.

Now since you're going to buy her a diamond, you don't have to worry about the 4 Cs of cubic zirconium...

...just remember the 5 Cs of diamonds: Cut, Color, Clarity, Carat, and Cost.

Now let's put all of this knowledge into action and go build an engagement ring with a great ring building tool.

This has been part 3 of 5 of "A Guy's Guide to Building an Engagement Ring"

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Diamond

From Wikipedia, the free encyclopedia.

Diamond is one of the natural allotropes of carbon (the main one being graphite). Sometimes known as adamant, it is the hardest known naturally occurring material, scoring 10 on the old Mohs hardness scale. The material boron nitride, when in a form structurally identical to diamond, is nearly as hard as diamond; a currently hypothetical material, beta carbon nitride, may also be as hard or harder in one form. The diamond derives its name from the Greek *adamas*, "untameable" or "unconquerable", referring to its hardness.

Diamond is a transparent crystal with a refractive index of 2.417, a high dispersion of 0.044, and a specific gravity of 3.52. Diamonds have a cubic crystal system consisting of tetrahedrally bonded carbon atoms. Diamonds have a perfect octahedral cleavage, which means that they have 4 cleavage planes. They sometimes have an conchoidal (like glass) fracture, sometimes irregular. The lustre of a diamond is described as *adamantine*, which simply means diamond-like.

Diamonds exhibit fluorescence of various colors under long wave ultra-violet light, but generally bluish-white, yellowish or greenish fluorescence under X-rays. Diamonds have a violet absorption spectrum at 415.5 nm. Colored stones show additional violet bands. Brown diamonds show a green band at 504 nm, sometimes accompanied by 2 additional weak green bands.

Except for natural blue diamonds which are semiconductors, diamond is a good electrical insulator, but unlike most insulators, is a good conductor of heat because of the strong bonding within the molecule. Specially purified artificial diamonds have the highest thermal conductivity (20-25 W/cmK, five times more than copper) of any known solid at room temperature. Natural blue diamonds contain boron atoms which replace carbon atoms in the crystal matrix, and also have high thermal conductance. Because diamonds have such high thermal conductance they are already used in semiconductor manufacture to prevent silicon and other semiconducting materials from overheating. Natural blue diamonds and synthetic diamonds doped with boron are p-type semiconductors. If an n-type semiconductor can be synthesized, electronic circuits could be manufactured of diamond. Worldwide research is in progress, with occasional successes reported, but nothing definite. In 2002 it was reported in the journal *Nature* that researchers have succeeded in depositing a thin diamond film on a diamond surface which is a major step towards manufacture of a diamond chip. In 2003 it was reported that NTT developed a diamond semiconductor device.

Type I diamonds have nitrogen atoms as the main impurity. If they are in clusters they do not affect the diamond's color (Type Ia). If dispersed though out the crystal they give the stone a yellow tint (Type Ib), the Cape series. Typically a natural diamond crystal contains both Type Ia and Type Ib material. Synthetic diamonds which contain nitrogen are Type Ib

Type II diamonds have no nitrogen impurities. Rarely, they contain no other impurities (Type IIa). Type IIb are the natural blue diamonds which contain scattered boron within the crystal matrix.

Diamonds occur in a variety of colors - steel, white, blue, yellow, orange, red, green, pink, brown and black. Colored diamonds contain impurities that cause the coloration, pure diamonds are always translucent and colorless.

In the late 18th century, diamonds were demonstrated to be made of carbon by the rather expensive experiment of igniting a diamond (by means of a burning-glass) in an oxygen atmosphere and showing that carbonic acid gas (carbon dioxide) was the product of the combustion. The fact that diamonds are combustible bears further examination because it is related to an interesting fact about diamonds. Diamonds are carbon crystals that form deep within the Earth under high temperatures and extreme pressures. At surface air pressure (one atmosphere), diamonds are not as stable as graphite, and so the decay of diamond is thermodynamically favorable ($\Delta H = -2 KJmol^{-1}$). So, despite De Beers' ad campaign, diamonds are definitely not forever. However, owing to a very large kinetic energy barrier, diamonds will not decay into graphite under normal conditions.

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The Diamond Industry

Due to their high dispersion (play of color), diamonds have been prized as a constituent of jewellery, and a large trade in gemstone-class diamonds exists, mostly controlled by the De Beers company, which has used its monopoly to control prices.

Marcel Tolkowsky's 1919 book on Diamond Design describes the history of diamond cutting since the late Middle Ages. Roughly 1900, the development of diamond saws and good jewelry lathes enabled the modern Round Brilliant cut. Tolkowsky determined a detailed design for this cut. His geometric calculations are in his book.

In the 1970s, Bruce Harding developed another mathematical model for gem

design. Since then, several groups have used computer models (e.g., MSU, OctoNus, GIA, and folds.net) and specialized scopes to design diamond cuts.

During the 1990s Israeli interests acquired about 20% of the diamond trade, buying diamonds from Russia and from mines in Africa not controlled by De Beers. De Beers now deals only in diamonds from their own mines. A major diamond cutting industry has grown up in Gujarat State, India where 90% of the world's diamonds are cut by a workforce of 800,000. Diamonds are valued according to the four C's of diamond grading, namely **color**, **clarity**, **cut**, and **carat**. Deep blue diamonds such as the Hope Diamond are particularly valuable as are blue-white diamonds generally.

80% of the diamonds produced are poorer quality (discolored, less transparent) diamonds which are used as industrial diamonds, where their extreme hardness is useful in cutting and grinding otherwise intractable materials (including other diamonds). Lately, gas-phase deposition processes have been devised that allow thin diamond films to be grown on some surfaces, greatly increasing the durability of some machine tools.

Diamonds typically have cubic symmetry. A second form called lonsdaleite with hexagonal symmetry is also found. The local environment of each atom is identical in the two structures.

Historically diamonds were found in alluvial deposits in southern India which are now worked out. Most diamond deposits are in Africa, notably in South Africa, Namibia, Botswana, the Republic of the Congo and Sierra Leone. Revolutionary groups in some of those countries have taken control of diamond mines, using the conflict diamonds to finance their continuing operations with baleful results.

There are also commercial deposits in the Northwest Territories, Canada in the Russian Arctic, Brazil and in Northern and Western Australia. Occasionally diamonds have been found in glacial deposits in Wisconsin and Indiana. The Wisconsin finds can be explained by recent Canadian discoveries, but the diamonds found in Indiana must have come from an as yet undiscovered source in Quebec as the movement of ice was from northeast to southwest. Tiny nanometer sized diamonds, often called nanodiamonds, are also found as presolar grains in primitive meteorites.

Diamonds were first produced artificially on February 16, 1953 in Stockholm, Sweden by the QUINTUS project of ASEA, Sweden's major electrical manufacturing company using a bulky apparatus designed by Baltzar von Platen. Pressure was maintained within the device at an estimated 83,000 atmospheres for an hour. A few small crystals were produced. The discovery was kept secret.

While large diamonds has up to now been more expensive to produce artificially than to mine, smaller artificial diamonds and especially diamond dust has become an important industry with General Electric at the forefront. As of 2003, at least two companies are planning to introduce high-quality

artificial diamonds, virtually indistinguible from the natural occuring ones, in an year or two. The traditional diamond industry is evaluating countermeasures (source: [1]).

A city of major importance in diamond trade is Antwerp.

Symbolism of Diamonds

Diamonds are often used to symbolize love and are often found in wedding bands.

Famous Stones

- Cullinan Diamond
- Hope Diamond
- Koh-i-noor
- Millennium star

External Links

- On conflict diamonds (UN)
- Article in *Nature* on the diamond chip
- Article in *Nature* on advancing techniques of growing diamond crystals
- OctoNus Software has posted several diamond cut studies, by various authors. OctoNus, Moscow State University, Bruce Harding, and others have posted work there.
- Gemological Institute of America

Further Reading

- *Diamond Design*, Marcel Tolkowsky. Web edition as edited by Jasper Paulsen. www.folds.net, Seattle, 2001.
- *The New Alchemists: Breaking Through the Barriers of High Pressure*, Robert M. Hazen, Times Books, Random House, New York, 1992, hardcover, 286 pages, ISBN 0-8129-2275-1

See also: List of minerals, Diamonds (card suit)

All Gem Stones

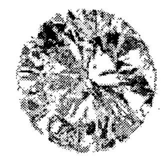
...a time to gather stones.

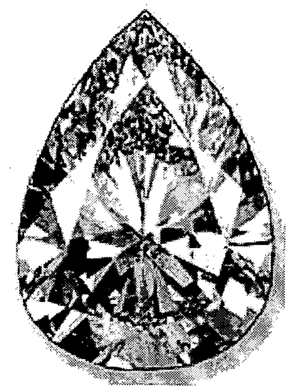
Diamonds are beautiful symbols of love around the world.

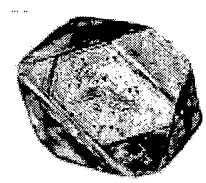
Stone's names: Diamond, Brilliant.

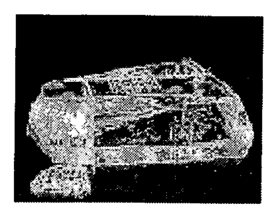
Color: Diamonds are usually colorless. However, brown, yellow, green, blue, purple, pink, red, gray and black variations are also found depending on the impurities present.

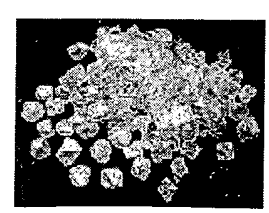
Description: ***C*** *Native carbon*
Diamond is a mineral composed of pure carbon. It is difficult to accept that chemically this brilliant gemstone is the same as black opaque graphite and even ordinary soot.
Diamond is the hardest natural substance, with a hardness of 10 on Mohs' scale, so it can be cut or polished only by another diamond. It can be identified by its hardness and adamantine lustre. Despite its extreme hardness diamond is brittle and at 4,289 degree C a diamond will completely burn up leaving nothing behind.
Diamonds are the most popular gemstone of all time. Diamonds used for jewelry are graded on the basis of color from blue-white to yellow. Grading also is done on the basis of purity, which varies











from perfectly clear, extremely pure stones to those with many impurities and flaws. Diamonds are said to be of the first water when very transparent, and of the second or third water as transparency decreases. Diamond stones are weighed in carats (1 carat = 200 milligrams) and in points (1 point = 0.01 carat).
The hardness, brilliance, and sparkle of diamonds make them unsurpassed as gems.

The name's origin: Diamond derives its name from the Greek word *adamas,* which means "invincible".

Birthstone: Diamond is the birthstone of Aries (Ram): March 21 - April 19.

Wedding anniversary: Diamond is the anniversary gemstone for the 30th and 60th year of marriage.

Care and treatment: Diamonds should be stored separately. They can scratch other jewelry as well as each other.

From the stone history: Diamonds from Indian deposits were known in ancient times. In the West the limited use of diamonds began in the late Middle Ages. The diamond, was thought to give its wearer strength in battle and to protect him against ghosts and magic.The first river-bed diamonds were probably discovered around 800 B.C.
Large demand provided an

incentive for the production of false diamonds as early as 1675 in Paris.
Only 20 per cent of diamonds are suitable for cutting as gems. The rest are discolored or contain flaws. Because of their extreme hardness, diamonds have a number of important industrial applications. They are used in drill bits, glass cutters, masonry saws for shaping building stone, and for cutting other diamonds.

Shopping guide: Diamonds are special gifts due to their glamour, rarity, durability and beauty. Diamonds are welcome gifts for all occasions. They are beautiful symbols of love around the world.
A diamond with proper proportions will send all light entering the diamond out of the top of the stone. This is considered an ideal cut and what you should be looking for.
If you want a nice diamond be prepared to pay a nice price. Low price means low quality.
Be aware of numerous imitations of diamonds: cubic zirconia, synthetic moissianite, synthetic rutile, strontium titanate, colorless topaz, colorless sapphire, and many others. Scratching glass is useless test as many imitations made of quartz, which also scratches glass. Consult a professional, independent retail jeweler to insure you are getting the real thing.
If you are making a large investment in a diamond make sure that you are getting a

diamond grading report from a reputable gemological laboratory.

Healing ability: Diamond is a great assistance for all brain diseases. It is beneficial in stomach area. Diamonds strengthen the owner's memory.

Mystical power: Diamonds give faith, purity, life, joy, innocence and repentance. They assist in developing concentration and in beeing straight-forward and honest. It is believed the diamond loses its brilliance with the health of the wearer, regaining it only when the owner recovers.
Diamond is an antidote to poison and is capable of detecting poison by exhibiting a moisture or perspiration on its surface. Supposedly, the higher quality the diamond, the better it supports these qualities.

Deposits: Diamonds are mostly found in Australia, Ghana, Zaire, Russia, USA (Arkansas, California, Colorado, and North Carolina), and Brazil.

Famous diamonds:

> **Jubilee diamond,** flawless, clear white diamond weighing almost 651 carats in rough form, it was found in the Jaegersfontein mine in South Africa in 1895. It was faceted into a cushion brilliant of about 245 carats in 1897, the year of Queen Victoria's Diamond Jubilee,

from which it takes its name.

Excelsior diamond, until the discovery of the Cullinan diamond in 1905, the world's largest-known uncut diamond. When found by a worker loading a truck in the De Beers mine at Jagersfontein, Orange Free State, on June 30, 1893, the blue-white stone weighed about 995 carats. After long study the Excelsior diamond was cut (1904) by I.J. Asscher and Company of Amsterdam into 21 stones ranging in weight from less than 1 carat to more than 70 carats.

Cullinan diamond, world's largest gem diamond, which weighed about 3,106 carats in rough form when found in 1905 at the Premier mine in Transvaal, S.Af. Named for Sir Thomas Cullinan, who had discovered the mine three years earlier, the colorless stone was purchased by the Transvaal government and was presented (1907) to the reigning British monarch, King Edward VII. It was cut into 9 large stones and about 100 smaller ones by I.J. Asscher and Company of Amsterdam, famed for their cutting of the Excelsior diamond, which until the discovery of the Cullinan had been the largest known

diamond. The stones cut from the Cullinan diamond, all flawless, are now part of the British regalia. The two largest are the largest cut diamonds known, and the larger of these is the Great Star of Africa, or Cullinan I, a 530.2-carat, pear-shaped gem set in the English sceptre. The other is the most valuable stone in the imperial state crown, the 317-carat Cullinan II, sometimes called the Second Star of Africa.

Hope diamond, sapphire-blue gemstone from India, one of the largest blue diamonds known. It is thought to have been cut from a 112-carat stone brought to France by the jewel trader Jean-Baptiste Tavernier and purchased by Louis XIV in 1668 as part of the French crown jewels. This stone, later called the French Blue, was recut into a 67-carat heart in 1673 and disappeared after the crown-jewel robbery of 1792. The 45.5-carat Hope diamond, named for the London banker Thomas Hope, who purchased it in 1830, was apparently formed from it. The Hope diamond is on display in the Smithsonian Institution, Washington, D.C.

Regent diamond, also called PITT DIAMOND, a brilliant-cut stone with a slight blue tinge that once

was the outstanding gem of the French crown jewels; it was discovered in India in 1701 and weighed 410 carats in rough form. It was purchased by Sir Thomas Pitt, British governor in Madras, who published a letter in the London Daily Post to counter rumours that he had stolen the gem. The stone was cut to a 141-carat cushion brilliant called the Pitt diamond and was purchased in 1717 by the Duke of Orleans, regent of France--hence its present name. In 1792 it was stolen along with other crown jewels but was recovered. Napoleon I wore the stone in the pommel of his sword. It has been on display in the Louvre since 1887.

Great Mogul diamond, the largest diamond ever found in India. It was discovered as a 787-carat rough stone in the Golconda mines in 1650 and subsequently was cut by the Venetian lapidary Hortentio Borgis. The French jewel trader Jean-Baptiste Tavernier described it in 1665 as a high-crowned rose-cut stone with a flaw at the bottom and a small speck within. Its present location is unknown, and some believe that either the Orlov diamond or the Koh-i-noor may have been cut from this stone after its loss following the assassination

of its owner, Nader Shah, in 1747.

Shah diamond, yellow-tinged stone of about 89 carats that bears three ancient Persian inscriptions, indicating it was discovered before 1591, probably in the Golconda mines in India. The inscriptions are to Nezam Shah Borhan II, 1591; Shah Jahan, son of Shah Jahangir, 1641; and Fath 'Ali Shah, 1826. Given to Tsar Nicholas I by Fath 'Ali Shah in 1829, it is displayed in the Diamond Fund of Russia in Moscow.

Orlov diamond, rose- cut gem from India, one of the Romanov crown jewels; it is shaped like half an egg, with facets covering its domed surface, and the underside is nearly flat. It weighs nearly 200 carats. According to legend, it was once used as the eye of an idol in a Brahman temple in Mysore and was stolen by a French deserter, who escaped with it to Madras. Others contend that the authenticated history of the Orlov extends to the middle of the 18th century, when the stone (believed to be the long-missing Great Mogul diamond) belonged to Nader Shah, king of Persia. After his assassination it was stolen and sold to an Armenian millionaire named Shaffrass. In either case, it

was purchased in 1774 by Count Grigory Grigoryevich Orlov, who in an unsuccessful attempt to regain favour gave it to Empress Catherine II the Great. Catherine had it mounted in the Romanov imperial sceptre, and it is now part of Russia's Diamond Fund (which contains the tsarist regalia) in Moscow.

Sancy diamond, fiery stone of Indian origin that is shaped like a peach pit and weighs 55 carats. It has a long history and has passed through many royal families. Purchased in Constantinople about 1570 by Nicolas Harlay de Sancy, the French ambassador to Turkey, it was lent to the French kings Henry III and Henry IV. Later it was purchased by Queen Elizabeth I of England and descended to the Stuarts. After the flight of James II from England to France in 1688, it reappeared among the French crown jewels of Louis XIV and was stolen with these in 1792. It reappeared in 1828, when it was purchased by the Russian prince Demidov, in whose family it remained until 1900. Later it became the property of Lady Nancy Astor.

Florentine diamond, clear, pale-yellow stone weighing 137 carats; of

Indian origin, it was cut as a double rose with 126 facets. Once owned by Charles the Bold, duke of Burgundy, who lost it when he fell in battle in 1477, the stone came into the possession of Pope Julius II and the Medici family early in the 16th century. Maria Theresa of Austria acquired it through her marriage (1736) to the Duke of Tuscany, and it subsequently became part of the Austrian crown jewels. Seized by the Germans when they took over Austria just before World War II, it was recovered by the U.S. 3rd Army and returned to the Viennese by Gen. Mark Clark.

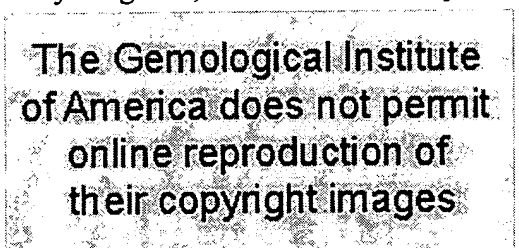
Star of the South, unblemished, 129-carat white diamond with a rosy glow, one of the largest ever found in Brazil; it weighed about 262 carats in rough form. It was discovered in 1853 in the Bagagem River (in Minas Gerais state) by a slave woman, who was given her freedom and pensioned as a reward.

Diamonds:Gemology

A Fancy Spectrum

Colored diamonds may be a big part of your future if their availability and growing popularity continue. Learn the basics so you can tell your customer their fascinating story

By curious flukes of nature, some very rare diamonds are born the colors of a rainbow. These are the diamonds for customers who have everything else, those who covet a jewel few others can own.



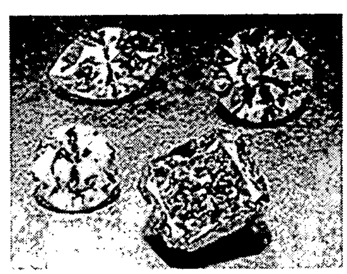
Once owned only by royalty, "fancy" diamonds have gone democratic this century, thanks to increased production in Australia, Brazil, Venezuela and parts of Africa where conditions are right for natural color.

Rough and cut diamonds in some of the rarest colors.

Their popularity and beauty also have spawned color-induced diamonds and synthetic colored diamonds. These are less expensive, of course, and further expand consumers' horizons in the diamond world.

Fancy This

A "fancy" diamond is a natural diamond of color – such as red, green, purple, violet, orange, blue and pink – and should not be confused with a "fancy cut," which refers to shape. Fancy colors vary from faint to intense.



Any diamond that falls between K and Z on the Gemological Institute of America's color grading scale can contain small amounts of yellow but not be considered fancy. Any yellow diamond beyond Z is a fancy color and, as such, commands a premium.

Causes of color – yellow and otherwise – are not as cut and dried as you might think. Infinitesimal impurities, irradiation or anomalies in crystal growth – or combinations of these factors – are the known causes of color. Here's a closer look at each one.

Prevalent fancy diamond colors include yellow and brown. Even some pinks are tinged with brown.

Impurities

It's curious how such practically negligible elements in diamond can cause such a riot of colors. For example, nitrogen (sometimes combined with hydrogen) results in many of the yellow and some of the brown shades.

Yellow diamonds are called "canaries" (referring to the yellow bird) or "cape series" (they were first found in Cape Province in South Africa). They are type Ia or Ib diamonds, which means they contain clusters or aggregates of nitrogen atoms. If your store has a spectroscope, you can see that Ia types show dark lines at the 415 nanometer mark, according to the GIA *Diamond Dictionary*. Ia types are quite prevalent in natural stones of weak, non-fancy yellow color.

Two extremely rare red and green rough diamonds. There's a reluctance to cut green rough because the color is often only "skin deep."

Natural Ib diamonds, which are related to saturated fancy yellows, are quite rare. Most synthetic fancy yellow diamonds are type Ib also. The color of natural light yellow diamonds can be deepened with irradiation and annealing (heating). Emmanuel Fritsch of Nantes, France, an expert on origin of color in diamonds, says combinations of irradiation and heating "cause color centers which reinforce the originally weak yellow color and, as a result, the treated gem becomes more marketable."

Type IIa diamonds contain boron or bits of nitrogen. While they are more often colorless, they also can be pink, blue-green or brown.

Type IIb diamonds are very rare and contain boron, which may substitute for some of the carbon atoms. They are most often blue.

Crystal Deformity

Some of the rarest and most coveted diamond colors are pink and red. The 20th century will be remembered for marketable quantities of these colors, mostly from the Argyle mine in Australia. Argyle has auctioned 50-60 of these diamonds annually for a little over a decade.

The cause of the color remains a mystery. Some speculate manganese inclusions impart color in thin bands in the crystal lattice. Others theorize it may be a perceived color due to crystal deformation – a missing atom causing a structural defect. It may be a combination of factors.

In an added twist, irradiation of type Ib synthetic diamonds has been known to create red.

Irradiation

Most green diamonds owe their color to natural irradiation, probably from radioactive minerals (such as uranium, thorium and potassium) in the kimberlite ore in which they are found.

Irradiation also causes some diamonds to turn brown or blue to violet.

Natural green is very rare. One way to tell the difference is to examine the "skin" of a cut green diamond. Color caused by irradiation is mostly concentrated in stains on the outer layer. Polishing can remove this layer and the color with it. Determination of color origin in green diamonds should be handled by well-qualified gemological laboratory.

Colored Diamond References

1. *The Nature of Diamonds,* edited by George Harlow. Cambridge University Press in association with the American Museum of Natural History. Cambridge, UK, 1998.
2. *Diamonds* by Fred Ward, Gem Book Publishers. Bethesda, MD. Revised edition 1998.
3. *Fancy-Colored Diamonds* by Harvey Harris, published in Lichtenstein by Fancoldi Registered Trust, 1994.
4. *Collecting and Classifying Coloured Diamonds* by Stephen C. Hofer, Ashland Press, New York City, NY, 1998.
5. *Gems & Gemology,* Winter 1994, "Color Grading of Colored Diamonds in the GIA Gem Trade Laboratory." John King, Tom Moses, James Shigley, Yan Lu.

– by Robert Weldon, G.G.

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CUT

Cut/make: How well it is cut determines a diamond's brilliance. It is the skill of the cutter that unlocks the natural beauty of a diamond, revealing all of its hidden fire and brilliance. Most diamonds are cut with a full 58 facets and it is important that these are cut to precise angles. A diamond that is cut well will reflect light from one facet to another and then back out through the top of the diamond. Only a well-cut diamond will really sparkle.

Definition

In its rough state, a diamond's beauty is well concealed. Through cutting, the magnificent optical beauty of a diamond is revealed. A diamond cutter's challenge is to balance beauty with weight retention from the rough diamond crystal.

In the best-case scenario, approximately 50% of the weight is lost from the original crystal in the cutting process. Because size is important to many consumers, often cutters sacrifice diamond beauty in order to save weight, maximizing the size of the finished diamond. Note that cut is also referred to as ***make***.

Shapes:

When the term "cut" is mentioned, most consumers think of shape, but shape and cut are different. Diamonds cut and fashioned in different shapes, including round brilliant, pear, oval, marquise, princess cut, emerald cut (rectangular), heart, and triangle. The most popular shape is the round brilliant. The other shapes are referred to as ***fancy-shapes***. Round brilliant diamonds retain less weight from the rough diamond crystal, and are generally more valuable than fancy-shaped diamonds.

Optical Beauty:

The way a diamond reflects and refracts light is dazzling to the beholder. There are four factors that determine the optical beauty of a diamond: luster, brilliance, dispersion, and scintillation.

Luster	The quantity and quality of light reflecting from the surfaces of a diamond.
Brilliance	The amount of ***white light*** returned to the eye from the diamond.
Dispersion	The amount of ***rainbow colors*** returned to the eye from within the diamond.
Scintillation	The ***sparkle***, which is the combination luster, brilliance, and dispersion when there is movement by the wearer or light source.

How Cut is Graded

In the past, diamonds were analyzed, not graded, for cut by visual estimation. Today, there are several electronic machines used to determine the angles and proportions relating to the quality of cut. A diamond's finish, including polish and symmetry, is graded by human examination through a binocular microscope.

Round Diamonds - The standards for quality of cutting a round brilliant diamond have been established by AGS and GIA using nearly 100 years of research. AGS and GIA Laboratories assign a numeric cut grade, complete with all the proportions and finish parameters for round diamonds.

Fancy Diamonds - Since the proportions for fancy-shaped diamonds vary the optimal balance of luster, dispersion and scintillation, is different for each shape. Therefore, no cut grade is assigned for fancy-shapes at this time.

Terminology

Ideal Cut	A diamond cut to optimal proportions, with optimal polish and symmetry, with the most weight loss to produce maximum luster, brilliance, dispersion, and scintillation. Diamonds cut to this standard are the most valuable, with only 5% of the round brilliant diamonds on the market cut to this standard.
Well-Cut	Diamonds that have very good optical beauty that fall just outside of the parameters of Ideal Cut diamond. These diamonds are priced less than Ideal cuts because they are not as rare.
Deep Cut	This diamond will appear smaller than it weighs because it's weight is retained in the depth. It is cut with a deep pavilion (bottom of the diamond) that does not reflect light back through the crown (top of the diamond). Light ***leaks*** out the pavilion producing a dark appearing diamond that lacks beauty. These diamonds are sometimes called ***nailheads*** due to their dark, face-up appearance.
Shallow Cut	Diamonds that are cut with shallow pavilions that do not reflect light back through their crown. The light leaks out from the pavilion, producing a washed-out or watery appearance that is not beautiful. Weight is retained in the diameter, making the diamonds appear larger than they weigh. These diamonds are sometimes called ***fisheyes***, due to unsightly reflections in the crown area.
Bow-Tie	Effect dark area in the center of some fancy-shaped diamonds. A large bow-tie shape in the center of a fancy shaped diamond detracts from beauty and lowers the value.

Cut in Relation to Value

Cut is the most important factor to a diamond's beauty. Regardless of the color, clarity, and carat weight, a well-cut diamond will be beautiful. Cut is so important to the value of a diamond that it can affect the value from 25% to over 50%.

Fancy-shaped diamonds, since they retain weight from unusual shaped rough crystals, are often less expensive then comparable round diamonds. Carat for carat, since fancy-shaped diamonds are elongated, they appear larger than round diamonds. If a consumer is interested in maximizing size appearance, they can buy a smaller, yet larger-appearing fancy-shaped diamond of the same quality for less than a comparable round brilliant diamond.

COLOR

Colour: Most gem diamonds seen alone appear white, but most have a hint of colour, mainly yellow. Diamonds with no trace of colour at all are extremely rare and the closer they are to no colour, the more rare and valuable they will be. Also rare are diamonds with a strong pure colour that are called "fancies" and which are very valuable. The Argyle Mine in Australia, which is the world's biggest diamond mine, produces the rare pink diamonds as well as beautiful cognac and champagne coloured diamonds.

Definition

The amount or presence of body color in a diamond.

Diamonds come in all colors of the rainbow, even more shades than any colored gemstone. The most rare diamond colors are red, pink, green, and blue. Diamonds that display enough of a hue, or nuance of color to be desirable, are called fancy-colored diamonds.

The absence of color in diamonds is most rare and highly prized. Most diamonds mined in nature have traces of yellow, some brown or gray. Color, in diamonds is caused by minute traces of other elements, such as nitrogen (yellow) and boron (blue).

Color is an important factor to beauty, rarity, and value because it is something a consumer can see without the aid of equipment. The range of color most often represented and sold in jewelry stores are:

AGS grades 0 - 3.0
GIA grades D - J

The colorless to the near colorless ranges.

AGS Colorimeter GIA Color Scales

AGS	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	
GIA	D	E	F	G	H	I	J	K	L

AGS	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5
GIA	M	N	O	P	Q	R	S	T	U

AGS	9.0	9.5	10.0
GIA	X	W	XYZ

The most rare grades, AGS 0 - 1.0 or GIA D - F, are considered to be in the colorless range and are the most valuable. Diamonds graded AGS 3.5 - 4.5 or GIA K - M show a visible yellow, brown, or gray body color face-up. Yet when these diamonds are well cut and set in yellow gold, they can be beautiful, brilliant, and represent good value.

How Color is Graded

The diamond in question is compared to a set of master diamonds under a balanced light source. Once the color match is made, an Alpha Numeric grade is assigned.

Terminology

Blue-White	According to the Federal Trade Commission, only a diamond that is either bluish in color or colorless may be referred to using this term, therefore it is NOT applicable in most situations.
Fluorescence	A unique quality possessed by some diamonds to give off light when exposed to specific ultraviolet wavelengths. It is an unusual quality that can enhance the appearance of a diamond in certain lighting conditions. When fluorescence is very strong, however, the diamond may have an oily appearance that detracts from the beauty and value. Only 50% of all gem-quality diamonds fluoresce, and only 10% strongly fluoresce. When gem-quality diamonds fluoresce it is a bluish color.

Color and its Relation to Value

Color is an important factor in the purchase of a diamond and can effect the price by 5 - 20% on each increment of the diamond grading scale. Since it is a factor a consumer can see, careful examination of each diamond under consideration is advised. This is especially true when considering a fancy-shaped diamond. For example, an emerald shaped diamond reveals the body color and clarity much more than other shapes, where even a slight trace of color may be easily discerned.

CLARITY

Clarity: Diamonds were formed millions of years ago, deep within the earth under enormous heat

and pressure. Consequently, most diamonds contain tiny marks, known as inclusions, which make each stone unique. The inclusions don't necessarily weaken the stone and when they don't interfere with the passage of light they do not affect its beauty. The fewer and smaller the inclusions, the more valuable a diamond will be.

Definition

The presence or absence of inclusions within the diamond and blemishes on its surfaces. These slight birthmarks of nature generally do not affect the beauty of a stone, but they almost always affect its price. Truly flawless diamonds are extremely rare and very valuable.

AGS	0	0*	1	2	3	4
GIA	Flawless	Internally Flawless	VVS1	VVS2	VS1	VS2

AGS	5	6	7	8	9	10
GIA	SI1	SI2	I1	I2	I3	

* with a comment in the Comments section of an AGS Report

How Clarity is Graded

A diamond's clarity grade is determined through examinations by an experienced grader, using a 10x magnification and also the assessment of the trained unaided eye. A lab utilizes binocular microscopes for clarity grading, which provides the best optical, lighting, and viewing conditions.

When a diamond is examined, the size, type, position, number, color, and relief of clarity features are observed. The diamond is always viewed with the trained unaided eye to check for relative visibility of clarity features.

Terminology

P rfect	Only a diamond that is flawless, colorless and well cut can be referred to by this term. Therefore, it is NOT applicable in most cases and should be avoided.
Carbon-Spot	Carbon-Spot Diamond is 99.95% pure carbon, and 25 different mineral inclusions or small crystals, have been found within diamond. These are not carbon spots, but rather small crystals that were trapped within the host diamond as it was forming in nature. The most common mineral found within diamond is diamond.

Clarity and its Relation to Value

Clarity is a rarity factor that affects diamond value by 5 - 20% for each increment on the diamond grading scale. In most diamonds purchased by consumers, the diamond has few to no features noticeable to the unaided eye. You simply cannot see the subtle differences in clarity without magnification. Most consumers opt for a less rare clarity grade, and select a rarer color and larger carat weight.

CARAT WEIGHT

***Carat weight*:** A diamond's weight is the simplest of its characteristics to measure and from the earliest times it was used to calculate a diamond's value. Diamond weight is measured in carats, and each carat is divided into 100 points A carat is equal to one-fifth of a gram.

Definition

A measurement of weight used in determining rarity in evaluating a diamond.

The term Carat is derived from the ancient ***Carob Seed*** from the locust tree, used as a medium of exchange on early ***pan-balances***. In the early 1900's the ***Metric Carat*** was established.

1 Carat = .2 Gram

There are 100 Points to a Carat. The AGS uses the international diamond standard tolerance for rounding which is 1/10 point.

Example .999 = 1.00 Carat.

Terminology

Full Carat	A diamond that weighs or rounds to 1.00 Carat.
Light Carat	A diamond that weighs slightly less than 1.00 Carat. Example .96 - .99. This IS NOT a full Carat. Diamonds in this range are priced less.
Magic Sizes	Diamonds that weigh in exactly at or greater than a major size category. Each major size category marks a greater degree of rarity, and commands a higher price.

Carat Weight and its Relation to Value

Carat weight usually has the greatest impact on value, based on rarity. Most people aspire to own at least a 1-carat diamond. DeBeers states, "fewer than 1% of all women will ever own a 2 carat or larger diamond". Most fancy-shaped diamonds are elongated in shape and appear larger than a comparable round brilliant diamond. In addition, fancy-shaped diamonds are priced less than round brilliants.

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GIA

THE FOUR Cs: A DIAMOND PRIMER welcome

next refresh glossary home

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GLOSSARY

Click a term to view its definition.

bench jeweler
brilliance
carat
clarity
diamond
dispersion
fancy colored
finish
GIA
Graduate Gemologist
metric carats
optical properties

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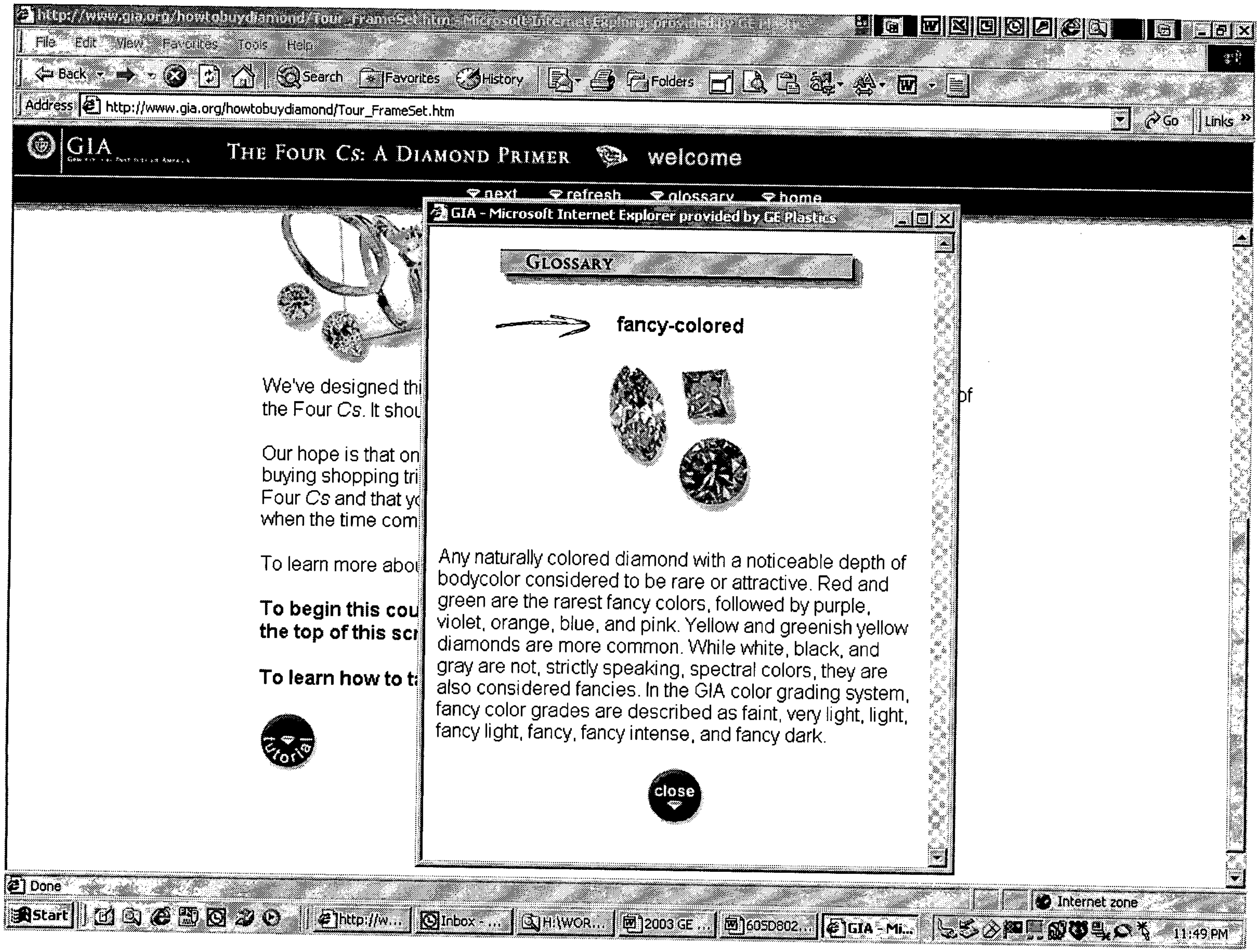
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GLOSSARY
fancy-colored
Any naturally colored diamond with a noticeable depth of bodycolor considered to be rare or attractive. Red and green are the rarest fancy colors, followed by purple, violet, orange, blue, and pink. Yellow and greenish yellow diamonds are more common. While white, black, and gray are not, strictly speaking, spectral colors, they are also considered fancies. In the GIA color grading system, fancy color grades are described as faint, very light, light, fancy light, fancy, fancy intense, and fancy dark.
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AZGem Gems

June, 2002

The World's Most Useful
Gem & Jewelry Monthly Newsletter

Written by Carolyn Doyle for customers of
The Dorado Company
and other visitors to the azgem.com website who subscribe.

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Usable Gems... and a little opinion.

Diamond Grades

Diamond grades are a great mystery to many people... **but it doesn't have to be that way!**

One reason for confusion is that more than one grading system is in use today.

Some systems old, some are modern, some are simplified commercial systems (AAA-White, or 1-10 for example) and some are technical.

The most commonly used, and probably the easiest to use is the system created by the Gemological Institute of America (GIA).

For our discussion this month we'll use the GIA system.

The 4 C's

We've heard of the Four C's for about as long as we can remember.

We know that the Four C's are:

- Color
- Cut
- Clarity
- Carat

But what is the significance of each C? Let's take them one by one.

Color

Diamond color grades run from colorless to light yellow.

A diamond breaks white light into the colors of the rainbow and returns all of those colors to your eye.

A colorless diamond does this better than a diamond with a tinge of color.

The GIA diamond color grading system uses letters to designate color grades.

As shown in the table below, the designations begin with D (colorless) and run through Z (light yellow).

Actually the color isn't always yellow. It can be green, brown, gray, or other colors.

Colorless	Near Colorless	Faint Yellow	Very Light Yellow	Light Yellow	Fancy
D E F	G H I J	K L M	N O P Q R	S T U V W X Y Z	Z+

The term ***fancy color*** is applied to any diamond with a distinct body color **other than** light yellow, light brown, or gray.

A fancy colored diamond has so much color that the color becomes the primary feature, much like a colored gem.

Probably the best known example of a fancy colored diamond is the Hope Diamond.

In the trade, color grading is done in a room with natural, north light.

The grader sits in a room with his/her back to windows facing to the north.

Usually all furnishings are a light gray color.

The grader has a set of master color stones, usually in color grades E, G, I, K, and M.

The grader compares the new diamond being graded to the master stones.

If the new diamond has less color than, say the G colored master stone, but more than the I colored master, then the new stone is graded as an H color.

Most jewelers don't have a north facing window, so they use a specially color balanced light that simulates daylight.

It is easier to distinguish a diamond's color by viewing the stone face down (from the back), or from the side, against a white background.

Cut

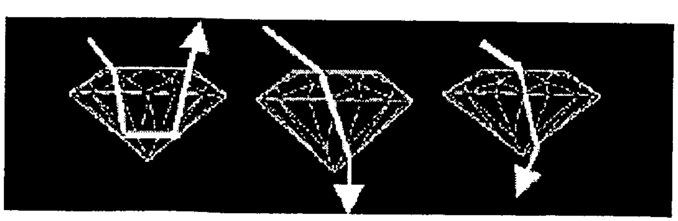
When grading a diamond's cut, the diamond's proportions, symmetry, and finish are considered.

Proportions are very important to a diamond's ability to return light to your eye.

Diamonds are cut to bend light down into the stone from the top (crown).

The lower (pavilion) portion is cut to bounce that light across to the opposite side.

The inside surface of that opposite side redirects the light back out through the top... and to your eye



A diamond cut to the wrong proportions and angles will let light leak out the sides or bottom of the stone.

Symmetry is the exactness of shape and placement of facets.

- A symmetrical round brilliant diamond will be round, not almost round.
- A symmetrical marquise shaped diamond will be twice as long as it is wide.
- A symmetrical pear shaped (or heart shaped) diamond will not have heavy shoulders.
- A symmetrical diamond will have facets that meet exactly at points and sides.
- A symmetrical diamond will have the table and culet facets exactly centered on the stone.
- A symmetrical diamond will not have extra facets. A round brilliant will have 58 facets.

In the trade symmetry is called **make**. A symmetrical diamond is said to have a good make.

Finish is the quality of a diamond's polish, and the condition of its girdle. Polish is important as a poor polish will interfere with light passing into and out of the stone.

Clarity

Clarity grading is where many people become confused.

Clarity grading isn't easy. It takes knowledge of the guidelines, and practice in applying them.

Usually the tools involved are simple... a pair of tweezers and a 10 power loupe to magnify the stone.

It does take practice to use a loupe well.

It's easier to see inclusions by looking into the diamond face down and from the side, but you always have to look at it face up to see how inclusions impact the stone's appearance.

In clarity grading you're looking for inclusions and blemishes.

Inclusions are tiny crystals of garnet, peridot, diamond, rutile, or other mineral that were trapped **inside** a diamond when it was formed.

Inclusions are not the fabled "carbon spots" you've always

heard about.

Some inclusions are (what looks like) tiny feathers. Many of these are small fractures inside the stone.

They can detract from the stone's appearance and ability to transmit light but usually don't make the diamond more vulnerable to breakage.

Blemishes are surface features like scratches or nicks.

The fewer inclusions present, the more desirable the diamond... all else being equal.

Here are the clarity grading guidelines from GIA:

Clarity Grade	Meaning	Definition
F	Flawless	Free from all inclusions or blemishes.
IF	Internally flawless	No inclusions visible 10x magnification.
VVS1	Very very slightly included #1	Inclusions that are extremely difficult to locate at 10x.
VVS2	Very very slightly included #2	Inclusions that are verydifficult to locate at 10x.
VS	Very slightly included #1	Minor inclusions that are difficult to locate at 10x.
VS2	Very slightly included #2	Minor inclusions that are somewhat difficult to locate at 10x.
SI1	Slightly included #1	Noticeable inclusions that are easy to locate at 10x.
SI2	Slightly included #2	Noticeable inclusions that are very easy to locate at 10x.
I1	Included #1	Obvious inclusions. Somewhat easy to locate with the unaided eye.
I2	Included #2	Obvious inclusions. Easy to locate with the unaided eye.
I3	Included #3	Obvious inclusions. Very easy to locate with the unaided eye.

Carat

The fourth C refers to the weight of a diamond.

As with other gems the unit of measure for diamonds is in carats.

A carat is one fifth of a gram.

A carat is divided into 100 parts, called points, so a half-carat diamond weighs 0.50 carats... or 50 points.

As the weight (and the size) of a diamond increases, its **per-carat value** increases.

For example, a one carat stone is worth significantly more than two half-carat stones.

Cost

Would you believe 5 C's?

Cost is also very important. At The Dorado Company we sell diamonds at **very good** prices.

But first you should go out and handle a few.

Put one on the back of your hand between the fingers to see how it looks against you skin.

When you start shopping for diamonds you usually want to see several diamonds of various grades, shapes, and sizes.

You may want to see what a half-carat round VS2 - G or a full carat marquise SI2 - H diamond looks like.

Once you have settled on a quality and size range, you can turn your attention to cost.

When you're shopping for diamonds get a quote from us.

Send a note to carolyn@azgem.com and let me know the...

- Shape
- Color grade
- Clarity grade
- Carat weight

I'll let you know what's available and quote you a good price.

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Carolyn Doyle

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Color

Diamond Search

Shape	Carat		Maximum Price
	Lowest	Highest	
Round	1.00	1.49	$

Color		Clarity		
Highest	Lowest	Highest	Lowest	
F	G	VS1	SI1	Go

Definition
The amount or presence of body color in a diamond.

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Color is an important factor to beauty, rarity and value because it is something a consumer

can see without the aid of equipment. The range of color most often represented and sold in jewelry stores are:

GIA grades D - J

The colorless to the near colorless ranges.

Color and its Relation to Value

Color is an important factor in the purchase of a diamond and can effect the price by 5 - 20% on each increment of the diamond grading scale. Since it is a factor a consumer can see, careful examination of each diamond under consideration is advised. This is especially true when considering a fancy-shaped diamond. For example, an emerald shaped diamond reveals the body color and clarity much more than other shapes, where even a slight trace of color may be easily discerned.

On to Clarity

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or Email our
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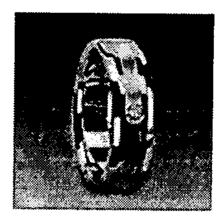

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Diamond Dictionary

The Diamond Dictionary is a good reference point when visiting internet diamond and jewelry sites and it's recommended that you print this dictionary because you'll find it an invaluable resource when considering buying certified diamonds, precious gems and precious metals.

Alternatively leave this window open and press "Control (CTRL)" and "F" simultaneously on your keyboard to begin searching this document from top to bottom as and when you need to. After you reach the bottom click the "up" radio button to search back up the document.

To reduce download times on this page there are no diagrams here, however you can view and print them from the **Diamond Drawings Page if you click here**.

It's not recommended that you try and learn all about jewelry terms by trying to read the document entirely in one go as it will stretch to seven pages on most printers and you'll get pretty bored even attempting it. Refer back to it as needed and you'll soon learn the basics of the Jewelry trade.

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(To print just the dictionary only, left click & drag your mouse to highlight just the dictionary and then print only the selected area using your print options.)

14K, 18K, 22K Gold	See 24K Gold. **[© www.diamond-engagement-rings-guide.com]**
24k Gold	24K = Pure gold which is fairly soft. Gold alloys such as 14k gold and colored golds are usually harder but of lesser financial value. 14k gold is characterized by having 14 parts pure gold and 10 parts added impurities such as metal alloys that can also be used to add coloring.
AGSL Diamond Quality Report	A Diamond Quality Document, issued by the American Gemological Society Laboratories, is universally accepted and respected by the jewelry industry as a document of authenticated quality.
American Gem Society Laboratories (AGSL)	**Independent** Gem graders and appraisers on equal par with the Gemological Institute of America (GIA). (see also Gemological Trade Laboratory) Does not include a valuation in it's diamond grading report.
Amethyst	A purple quartz gemstone.
Appraisal	An estimation of the value of Jewelry and precious gems, usually for insurance or verification purposes. **Always use an independent appraiser.**
Baguette	Small rectangular (sometimes tapered) cut diamond used for accenting and trim.
Bench Jeweler	A bench jeweler is a highly skilled craftsman who makes or repairs jewelry, working with diamonds, colored stones, and precious metals.
Bezel Setting	An enclosed or semi enclosed cylindrical head that is used in place of prongs to hold a

	gem stone in place.
Birthstones	Precious or semi-precious gemstones (see also gemstones).
Blemish	A surface imperfection like a cavity or scratch.
Blue white	Beware any dealer using this term to describe diamonds. It's a very vague term that describes a diamond's coloration characteristic.
Body color	The color of a diamond viewed under ideal light against a neutral colored background free from surrounding reflections.
Brilliance	The combination of all the white light reflections from the surface and the inside of the stone - it gives a polished diamond its brightness.
Brilliant Cut	A cut that is designed to maximize the brilliance of a diamond, often mistaken as a *round* brilliant cut because all facets appear to radiate out from the center of the diamond toward its outer edges. Brilliant cuts come in all shapes from square to oval.
Canary Diamond	Trade term for bright yellow/green, yellow/orange diamonds.
Cape	Trade term for diamonds with a distinct yellow tint when viewed directly from above.
Carat Weight, Carats	Unit of weight for precious stones, NOT to be confused with Karat which is the unit of weight used for grading precious metals. Prices increase exponentially for larger carats. E.g. A 1 carat diamond is more valuable than four 1/4 carat diamonds put together. 1 Metric Carat = 200 milligrams = 100 Points.
Carbon Spots	An often misused term that refers to included crystals that have a dark appearance, rather than a white or transparent appearance, when viewed under a microscope.
Carbons	See Pin Points.
Cavity	A hole or indentation in the surface of a diamond.
Certified Diamonds	See diamond grading certificate.
Champagne Diamond	A trade term to describe light yellow diamonds with green or brownish tint that lacks the intensity of more desirable colored and colorless diamonds.
Channel Setting	Describes a shank (or similar) with two or more channels fashioned into the center portion of the band that runs along the circumference of the shank adjacent to each side of the head. Each channel is then set with multiple gemstones. Channel settings can also run the entire length of the shank and are also used in other forms of jewelry such as bracelets and pendants.
Chip	A small irregular "chunk" of diamond originating from a larger stone. A small surface imperfection in a diamond indicating a missing chunk.
Citrine	A pale yellow to red-orange quartz gemstone NOT to be confused with Topaz.
Clarity	Describes the incidence or lack of imperfections inside and on the surface of a jewel or diamond.
Clarity Enhanced	Indicates a diamond that has been treated to improve its appearance, usually by laser drilling or filling of imperfections with transparent glass like material. If the diamond is filled in any way then it may not be a permanent treatment and as such G.I.A. refuses to quality grade any such diamonds. Laser drilling is permanent and is seen as acceptable although a stone should be re-graded and marked as having been laser drilled. Value should be reflected accordingly.
Clean	A misused and misleading term to be aware of describing the clarity of a diamond.
Cleavage	The propensity of crystalline minerals, such as diamond, to split in one or more directions either along or parallel to certain planes, when struck by a blow.
Cleaving	The act of splitting a gemstone such as diamond along a line of internal weakness NOT to be confused with cleavage.
Clouding	Severe imperfections in the clarity of a diamond caused by a grouping of very small imperfections.
Color	Describes the individual hue of a diamond usually used in the context of the relative lack of color that a diamond possesses. Although it's become fashionable to a certain extent to cherish "fancy colored diamonds".
Colorless	A diamond with absolute zero body color and complete transparency.

Commercially Perfect / Commercial White	Two more misleading terms to be aware of and avoid because they are ambiguous "insider speak".
Conchoidal Fracture	A mineral's habit of fracturing to produce curved surfaces like the interior of a shell (conch).
Corundum	Red corundum is called ruby all other colored corundum is called sapphire- the most famous being blue sapphire. It's the second hardest mineral, although diamond can be 4 to 100 times harder.
Crack	A fracture associated with cleavage that's usually irregular in shape and normally extends to the surface of a stone.
Crown	The portion of a diamond found above the girdle.
Crown Angle	The angle at which a diamond's bezel facets (or, on emerald cuts, the row of concentric facets) intersect the girdle plane. See also crown height percentage.
Crown Height Percentage	Expresses how deep the crown is compared to how wide the diamond is. A Deviation from the ideal will cause reduced brilliance and fire.
Cubic Zirconia / CZ	Man made diamond alternative, but in NO way has the same properties or value as a real diamond.
Culet	A small facet that appears parallel to the table but at the bottom of the diamonds pavilion. It's an older practice that is used to help prevent damage to the diamonds tip.
Cut	The shape and proportions of the finished gem.
Depth Percentage	Expresses how deep the diamond is in comparison to how wide it is. This depth percentage of a diamond is important to its brilliance and value, but it only tells part of the story.
Diamond Grading Certificate	Describes a certificate that an **independent** gemological trade laboratory issues as a guide to the quality of a specific diamond.
Dispersion	The separation of white light into it's component "Rainbow Colors".
Emerald	A bright green highly prized transparent gemstone belonging to the Beryl family of minerals. Much less hard than diamonds. Less hard than ruby or sapphire.
Emerald cut	A rectangular eight sided gem such as a diamond with long parallel facets on the crown and pavilion. NOT to be confused with an Emerald Gem.
European Gemological Laboratory (EGL)	**Independent** Gem graders and appraisers (see also Gemological Trade Laboratory) Does not include a valuation in it's diamond grading report.
Eye Clean	Another often misused term to be aware of that describes the absence of inclusions when viewed without magnification under ideal lighting conditions.
Facet	A flat angular surface polished onto the surface of a diamond. A diamond has up to 7 facet types: Table, bezel, star, upper girdle, lower girdle, pavilion main and culet.
Face Up	A view of the top of a gemstone directly from above.
Fancy Colors	Brightly colored diamonds that cannot be mistaken for any kind of clear diamond that may have hints of coloration only.
Fancy Cuts	Any cut that is not round brilliant.
Feather	An internal crack or fissure with the appearance of a feather.
Filled Diamond	A diamond that has had a transparent material applied to a crack, chip or cavity. This might not be a permanent modification and as such these stones are often sold without a grading certificate because G.I.A. won't re-grade such stones.
Finish	The quality of a diamond's polish, the condition of its girdle, and the precision of the cut.
Fire	The amount of light dispersion that a particular diamond displays.
Fish Eye	A term that describes a shallow cut diamond with a notable lack of brilliancy that looks like a fish eye when viewed from above because light is passing straight through the stone instead of being reflected back from it.
Flaw	An external or internal imperfection in the diamond.

Flawless	A very rare diamond that is classified as having absolute zero flaws and blemishes when viewed at 10x magnification by an expert under ideal lighting conditions. (Most jewelers will never get to see one outside of a classroom or laboratory).
Fluorescence	Blue, yellow or white "Glow" seen on a diamond seen under ultra-violet or strong sunlight which sometimes spoils clarity. However, sometimes it will enhance a diamond.
Four C's	Used to describe the dimensions, quality and size of a diamond, Cut, Clarity, Carats, Color.
Fracture	See definition of crack.
Fracture filled	See filled diamond.
Full Cut	A round diamond with a full 58 facets.
Garnet	A natural gemstone that appears in many colors from pinky red to orange, yellow, brown or green.
G.E. Diamonds	Refers to Diamonds that are enhanced using General Electrics heat and pressure treatment to reduce coloration (increase colorlessness) in diamonds.
Gem Certification & Appraisal Lab (GCAL)	As a final double check GCAL warrants that each diamond meets the grades and measurements noted in the GIA or AGSL grading report, within recognized gemological tolerances.
Gemiscope	A microscope used for examining gemstones.
Gemological Institute of America (GIA)	**Independent** Gem graders and appraisers on equal par with the American Gemological Society Laboratories (AGSL). (see also Gemological Trade Laboratory) Does not include a valuation in it's diamond grading report.
Gemological Trade Laboratory (GTL)	A laboratory that researches and reports on quality issues regarding gemstones. Avoid in-house "retail biased" laboratory reports.
Gemologist	Anyone can call themselves a Gemologist - Be Very Careful!!! - See graduate gemologist.
Gemstone	A gemstone is the naturally occurring crystalline form of a mineral which is desirable for its beauty. There are over 30 different varieties and infinite color variations. They are commonly linked to birth dates and astrology and are even mentioned in the bible. Most gemstones are naturally imperfect but this adds a certain amount of character. Large mounted gemstones are often flanked with smaller gemstone or diamond clusters that help protect relatively soft stones.
GIA Diamond Dossier Report	A Diamond Grading Report, issued by the Gemological Institute of America presents a report of the characteristics of a diamond. The Diamond Dossier is a special report issued for diamonds weighing less than 1 carat.
GIA Diamond Grading Report	A Diamond Grading Report, issued by the Gemological Institute of America presents a report of the characteristics of a diamond.
GIA Diamonds	Diamonds that have been graded and appraised by the Gemological Institute of America.
Gold (Yellow Gold)	Pure gold is yellow in color and is represented as 24 Karats but is too soft to be worn as jewelry. So it's mixed with other alloys to form harder but less pure gold that is non hypoallergenic. Depending on the color of the alloys that are added, gold can become colored gold such as rose gold or white gold. See also 24K Gold.
Graduate Gemologist	Only a person who has undertaken and passed the five studies of "Diamonds, Diamond Grading, Colored Stones, Colored stones grading and Gem identification is qualified as a graduate Gemologist. NOT to be confused with GTL grader.
GTL Grader	A Gem Trade Labs grader simply grades gems for the wider gem industry and isn't usually identified with retailing or appraising retail trade gems. NOT to be confused with Graduate Gemologist.
Girdle	The edge of a gem that usually separates the top and bottom portions of a stone that can sometimes be cut too thin or too thick. (Thickness adds carat weight)
Head	The portion of a ring's mounting that clasps the stone.
Heart Shape	A gem's cut that makes the stone heart shaped.

Heat Treated /Pressure Treated	A fairly new diamond enhancement technique pioneered by General Electric primarily used to remove yellow coloring found in diamonds. NOT to be confused with the legitimate heating of corundum and other gemstones to improve color saturation.
Hearts And Arrows	Hearts & Arrows cut diamonds are gems that, thanks to the work of expert cutters and polishers, seem to possess inside a pattern of hearts and arrows when viewed with a hearts & arrows viewer. These diamonds are extremely well cut and provide a superb amount of brilliance and sparkle.
Hypoallergenic	Having a decreased tendency to provoke an allergic reaction.
Ideal Cut	The "Ideal Cut" is a cut based on a specific set of proportions for a round brilliant diamond proposed by gem cutter Marcel Tolkowsky in 1919. While Tolkowsky's original theories presented only one particular combination of proportions for creating the best balance of brilliance and dispersion, today the American Gemological Society recognizes any diamond falling within a narrow range of proportions and finish quality as being an "Ideal Cut" (also called an "AGS 0").
Ideal Lighting	Refers to full spectrum lighting that isn't usually present in outdoor conditions or home lighting. It's commonly found at your local jewelry store and in jewelry workshops and gemstone grading laboratories.
Inclusion	A visible foreign substance, imperfection or crystal trapped inside a diamond when it is formed deep underground.
Included Crystal	An enclosed crystal that can be dark or light found within a diamond which can spoil clarity.
Industrial Diamond	Diamonds not suitable for Jewelry making are used in a wide variety of industrial and commercial cutting and drilling machines.
Internally flawless	A term to describe diamonds that have no internal inclusions or imperfections when viewed by an expert using 10x magnification under ideal lighting but have external blemishes of some kind. NOT to be confused with flawless.
International Gemological Institute (IGI)	The first **independent** gemological institute founded in Antwerp, set up in 1975 as an independent gem appraiser to assess and grade precious gems initially for the Jewelry trade and later for the benefit of consumers. (see also Gemological Trade Laboratory)
Irradiated	Describes a gemstone that has been subjected to strong radiation. This can alter the stone's color and the treatment is usually finished off by being exposed to high heat and pressure.
Jewelers Vigilance Committee (JVC)	A not for profit organization set up in 1912 to protect consumers and ethical Jewelers.
Karat weight, Karats	A unit that is used to describe the weight value of precious metals, NOT to be confused with carats which are applied to gemstones. Pure gold is expressed as 24 karats.
Laser Drilled	A pinhole sized shaft invisible to the naked eye, created with a laser that reaches into the interior of a diamond in order to facilitate clarity enhancement techniques. This usually involves the use of acids (not harmful to diamonds) to clean out dark inclusions.
Laser Enhanced	A technique in which a fissure or crack is "Laser Welded" or filled.
Length To Width Ratio	See Ratio
Loose Diamonds	Diamonds that haven't been set into a piece of jewelry.
Loupe	An eyepiece usually black or silver in color, held to the eye in order to view a gem under magnification. For proper examination of a diamond it must be of at least 10x magnification.
Loupe Clean	Another ambiguous trade term to be wary of meaning that a diàmond's clarity remains "clear" when viewed with a loupe. Be aware that some loupes do not have strong enough magnification to render the test valid.
Make	A term used to describe the overall proportions and finish of a cut diamond.
Marquise Cut	A boat shaped (stretched oval) that is pointed at both ends.
Master Diamonds	A set of diamonds that are color verified for body color and are used for comparison purposes against other diamonds.

Mixed Cut	A cut in which either the crown or pavilion of a diamond is cut as a brilliant cut, and the other part of the diamond is cut as a step cut.
Moissanite	Another of the man made diamond substitutes that is superior in strength and toughness to cubic zirconia but inferior to diamonds. Cubic zirconia is actually closer in optical properties to diamonds than moissanite. Moissanite is also naturally greenish in color.
MOHs Hardness Scale	To measure hardness, the jewelry industry uses the Mohs Scale. This gem-trade standard, conceived by Friedrich Mohs in the early 1800s, measures the ability of a gem or mineral to resist abrasion damage. Diamond is placed as the hardest substance at 10, while talc is considered the softest at 1. Rubies and sapphires rate at 9, topaz and spinel at 8 and quartz material (such as amethyst and citrine) at 7.
Mounted Stone	A diamond or gemstone set in the head of a ring.
Mounting	A piece of Jewelry that holds a gemstone, comprising a shank and a head.
Naturals	The small areas of untouched and unpolished portions of a cut diamond.
Nick	Very similar to a chip but less severe in appearance.
Octahedron	Most rough diamonds exit the ground as an octahedron comprising a representation of two pyramids stuck together at the base.
Old European/ Old Mine Cut	A diamond with a round girdle outline. It will usually have a high crown, a small table, a deep pavilion and a large culet.
Opal	Opal is a non-crystalline gem that is formed in the ground when silica is liquefied and washed into fissures in the surrounding rock where it solidifies into a hardened gel. Tiny silica spheres create a pattern in opal that causes a prism-like effect that produces flashes of color and is sometimes considered the "Queen of Gems," because it encompasses the colors of all other gems.
Optical Properties	Those characteristics of a gemstone which govern its interaction with light.
Oval Cut	Oval shaped diamond that is rounded at both ends.
Pavé	A style of jewelry setting in which numerous small diamonds are mounted close together to create a glistening diamond crust that covers the whole piece of jewelry and obscures the metal under it.
Pavilion	The portion of a diamond below the girdle.
Pavilion depth percentage	Expresses how deep the pavilion is compared to how wide the diamond is.
Pear Cut	Pear shaped diamond resembling a teardrop.
Perfect	Flawless and colorless when viewed by an expert at 10x magnification under ideal light. The rarest, most expensive diamonds of all.
Perfect Cut	A stone cut to ideal proportions thus giving maximum brilliance NOT to be confused with perfect.
Peridot /Olivine	A green gemstone that is most striking in its lime green state. NOT to be confused with Emerald which is much more brilliant in appearance.
Pin Point	A small black rounded inclusion that appears on or near the surface of a diamond.
Platinum	The most precious of all metals, very rare and very hard. Often used in the construction of the head of a ring that holds a diamond because it's much harder than gold. Platinum jewelry has come more and more fashionable over the past two decades. It's also hypoallergenic. Only platinum that is 95% pure (950 parts per thousand is allowed to be termed pure platinum.
Points	A point is the unit of weight equal to one one-hundredth of a metric carat (0.01 ct). 1 Metric Carat = 200 milligrams = 100 Points.
Polish	The act of applying facets. The act of shining the surface or removing minor blemishes. A diamond grading term: Refers to the quality of the exterior finish of a diamond after the cutting and polishing process is complete.
Polished girdle	Most girdles are left as near as rough diamond as possible, the more material that is removed the less carat weight is retained. Polished girdles only slightly enhance the

	stone but definitely remove weight.
Pressure Treated	See heat treated
Princess Cut	A square or shallow rectangle shaped diamond with brilliant faceting above and below the girdle.
Proportions	Proportion refers to the angles and relative measurements of a polished diamond. More than any other feature, proportions determine a diamond's optical properties.
Radiant Cut	Similar to the princess but with additional faceting on each corner.
Rap Sheet	See rappaport sheet.
Rappaport Sheet.	Since the 1970's, Martin Rappaport has published the Rappaport Diamond Report for the diamond and jewelry trade. Today it is considered the primary source of diamond guide price information and is used in diamond markets world-wide as the basis for establishing inter-dealer prices.
Ratio	A comparison of how much longer a diamond is than it is wide.
Reflection	The bouncing of light from the internal and external surfaces of a diamond.
Refraction	The natural action of the prismatic altering (bending) of the angle of light as it enters a diamond.
Rose Gold	See Gold.
Rough Diamond	The properties of a diamond before it is cut and polished.
Round Brilliant Cut	A round shaped diamond with 58 facets (57 if there is no culet), representing the most efficient cut from a rough octahedral diamond.
Ruby	See Corundum.
Sapphire	See Corundum.
Scintillation	Sometimes called "sparkle," scintillation refers to the tiny flashes of light when the diamond, the light source, or the observer moves.
Semi Mount	A ring shank that doesn't yet have a center stone placed in the head.
Setting	A piece of jewelry that holds a gemstone comprising a shank and a head.
Shank	The circular band portion of a ring that holds the head. The head holds the stone. The shank and head make up a setting.
Side Stones	Stones set on either side of a larger central stone.
Signature Diamonds	Hand picked diamonds that are exclusive to the Blue Nile jewelers.
Single Cut	A smallish diamond with a very small amount of facets usually 16 or 17.
Solitaire	A French word meaning alone. In jewelry terms a ring (or other) set with a single gem.
Spread	A diamond cut in order to maximize carat weight - see fish eye.
Step Cut	A cut in which facets are arranged in concentric rows around the table and the culet.
Symmetry	A grading term for the exactness of shape and placement of facets.
Synthetic Diamond	Unlike Cubic Zirconia or Moissanite a synthetic diamond has all the properties of a real diamond except that it's man made.
Table	The flat octangular facet found right on the top of a diamond.
Table Percentage	The value which represents how the diameter of the table facet compares to the diameter of the entire diamond. The larger the table percentage, the greater the brilliance and the lesser the fire, and vice versa.
Tanzanite	Discovered in Tanzania just over 30 years ago: A prized purplish blue gemstone comparable to sapphire, it also appears in other colors. It's considered a fairly soft gemstone that can easily wear if treated harshly.
Tension Setting	Describes a shank with an opening for a stone that is pre-tensioned to hold a stone tightly in place. The shank is essentially open and is not a complete circle.
Tiffany Setting	A simple but stylish shank with a four or six prong head designed to accentuate the diamond and not the shank.
Titanium	One of the strongest metals on earth, titanium is also extremely hypo-allergenic and suitable for jewelry making amongst other modern applications. Although it's not

	viewed as a precious metal in jewelry terms it's popularity is increasing.
Topaz	A colored gemstone similar but more valuable than Citrine. It appears in yellow, orange, red, blue and green colorations. It is the hardest of the silicate minerals.
Tourmaline	Tourmaline is a complex aluminum and boron silicate mineral available in every color and saturation and even in combinations of two or three colors. This tough crystal has become a popular substitute for rubies, emeralds and sapphires as well as a fine gem in its own right.
Treated	A diamond that has been altered by any process other than cutting or polishing.
Trillion Cut	A triangular shaped diamond.
Tsavorite	A green member of the garnet family.
Turquoise	Turquoise is an opaque mineral with a color range from blue to green to yellow-gray, while the stone's waxen luster only enhances its color. Oxides contribute to the stone's famous gray, brown or black veining.
Wavy Girdle	An uneven girdle caused by cutting a diamond with less than an average symmetry.
White gold	Is created from yellow gold by adding silver colored alloys to give a white appearance. It still retains a yellow hint and is a cheaper alternative to platinum. See also 24k Gold. Sometimes it comes Rhodium plated (platinum family) to whiten the color and add hypoallergenic qualities.
Yellow gold	See Gold.

N.B. This diamond dictionary is not intended as a Jewelers bible, but rather a small consumer's reference library. It's been researched and presented to be as accurate as possible. This site cannot be held responsible for any misuse of this diamond dictionary.

Home Page>>>

Diamonds

Weight ✦ Color ✦ Clarity ✦ Cut

Diamonds reside in a prestigious class all their own, with a history that dates back to the 15th century. The first recorded diamond engagement ring was bestowed to the fiancée of an Austrian prince in 1477. From this time forward, diamonds have been the representation of love and promise of marriage. Over the years, people began to purchase diamonds to celebrate important events in their lives such as anniversary, marriages, achievements, and engagements, or to simply reveal an expression of love. Technological advances have allowed for accurate cutting, polishing and finishing of diamonds. These improvements are responsible for the vast number of styles and cuts that are on the market today. This wide variety of gems and price ranges will easily fulfill everyone's taste and budget.

THE 4C'S

The four Cs are defined standards of comparison that allow for the buying and selling of this precious gemstone. The Gemological Institute of America (GIA) created a universally accepted diamond grading system based on the four Cs of the diamond: **carat weight**, **color**, **clarity**, and **cut**.

Carat weight Refers to the unit of weight used for diamonds and other gemstones articulated in carats. 100 points equals to 1 carat.

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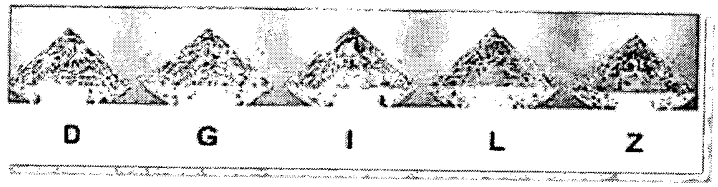
Color is defined by the amount of body color in the diamond. The grades for color indicate the amount (saturation) of color and range from colorless (D) to very saturated (Z). Colorless diamonds are rare and most diamonds have a very slight hint of yellow, brown or gray. The increased popularity of diamonds with some body color, has given rise to the prettier brown shades being sold as "champagnes" and "cognacs". Diamonds that have a body color other than light yellow or light brown (for example: pink, red, blue, green, or orange) are referred to as "fancy" diamonds and are graded differently. GIA Grading Scale (Fancy colored diamonds not included): GIA Color Grade Definition

D E F	G H I J	K L M	N O P Q R	S T U V W X Y Z	Z+
Colorless	Near colorless	Faint Yellow	Very light yellow	Light yellow	FancyYellow

Example:



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Clarity defines the absence or presence of external (blemishes) characteristics and internal (inclusions) features under the jewelry industry standard of magnification, 10 power (10x). The quantity of inclusions along with their size, color, relief and location determines a diamond's clarity grade. These characteristics also can impact a diamond's durability and beauty. Clarity grades range from flawless (FL) to heavily included. Flawless diamonds are very rare and practically all diamonds have inclusions. Every diamond is unique and its inclusions are actually identifying characteristics. SI (slightly included) and I (included) clarity grades are less rare, commonly used in jewelry and more affordable.

GIA Clarity scale: (all grades based on 10x magnification)

FL	IF	WS1 WS2	VS1 VS2	SI1 SI2	I1 I2 I3
Flawless	Iternally Flawless	Very, Very Slightly Inclusions	Very Slight Incliusions	Slight Inclusions	Imperfect

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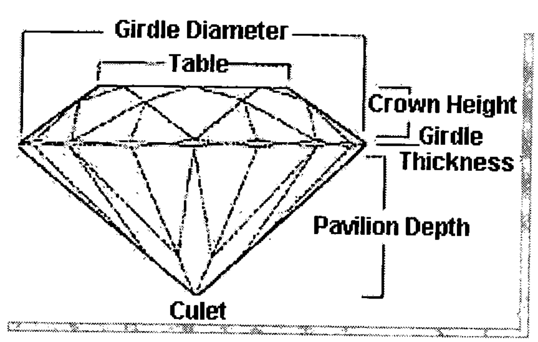
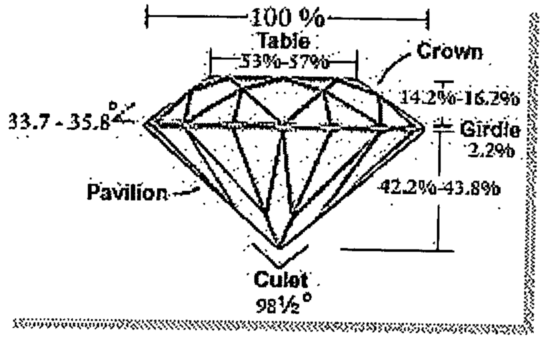
Cut has two implications. The term cut sometimes refers to the shape of a stone, for example: round, oval, pear, marquise, heart or emerald. More commonly and importantly, cut or "make" refers to a diamond's proportions, the correlation between its size (carat weight), shape, and cutting angles. Finish describes a diamond's facet symmetry and polish. Cut is important because it impacts a diamond's ability to redirect light through it and back to your eye. Cut is the main reason why some diamonds look lively and others appear dull or watery. Brilliancy or sparkle refers to the flashes of white light reflecting off a diamond. Dispersion or fire is the term that describes the flashes of rainbow colors that diamonds have. The cut of a diamond is essential in achieving the maximum light return and directly influences the diamond's beauty. Historically diamonds were purchased by a man for a woman, either as a gift or to symbolize a wedding engagement. However today, with a majority of women in the workforce, they are a popular self-purchase item.




100 %
Table
53%-57%
Crown
14.2%-16.2%
33.7 - 35.8°
Girdle
2.2%
Pavilion
42.2%-43.8%
Culet
98½°

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Reciprocal Space Mapping of Planar Defects in Diamond

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High-resolution reciprocal-space maps of localized regions around Bragg reflexions from natural and synthetic diamonds have been obtained with monochromatized (λ=1 Å) synchrotron radiation on the new six-circle diffractometer at Station 16.3. For the measurements described here, which were by way of an investigation into the capability of the technique to illuminate a field of long-standing but continuing interest, the diffractometer was used with a double-reflexion monochromator and a double-reflexion analyzer.

Natural diamond

In the most common variety of natural diamond (Type Ia), platelet precipitates of diameters 10 to 100 nm (or more) are found lying on {100} planes. In diffraction, these cause 'spike' extensions of reflecting power in <100> directions. The precise structure of platelets in natural diamond is still unknown but they are thought to contain a small proportion of nitrogen. The exceptionally high thermal conductivity of diamond is unfortunately substantially reduced by phonon scattering at platelets.

The maps of reciprocal space near several Bragg reflexions show the spikes extending outwards over relatively long reciprocal distances. At the 111 reciprocal lattice point (relp) there are spikes in all six <110> directions. Figure 1 shows for the first time in high-resolution diffractometry with beautiful clarity the four spikes lying in the (001) plane. We confirmed also that at the 311 relp there are four spikes, at the 331 relp there are spikes parallel only to [001], and at the 333 relp there are none. These results support the evidence that the lattice displacement associated with a platelet is approximately one-third of the lattice parameter.

Each spike in a reciprocal-space map represents scattering by disk-like platelets lying in parallel planes. The average diameter of the platelets determines the width of the spikes. Measurements made on the maps recorded gave an estimate for the average platelet diameter of 190 Å. This compares with results of 100 - 800 Å obtained earlier [1].

For the specimen investigated, the spike intensity was found to decrease with distance from the centre of the relp according to an inverse square law (as expected from a simple theory assuming relatively large platelets). In an X-ray topographic study [2] of a different diamond containing a large population of small platelets (only 16 nm in average diameter), an inverse 1.5 law was found to give the best fit with experiment.

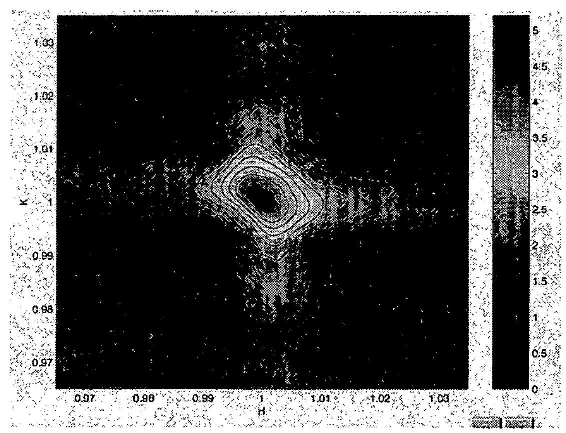

Figure 1. High-resolution reciprocal-space map of the 111 reflexion of a natural diamond showing four (of the six) spikes lying in the (001) plane, caused by platelet defects.

Synthetic diamond

In synthetic diamonds grown at high pressure and high temperature (HP/HT), small variations in growth parameters can cause banding within individual growth sectors, which is revealed by birefringence microscopy and by X-ray topography. The small variations in lattice constant (typically up to 100 parts per million) can give rise to structure surrounding Bragg reflexions in reciprocal space. Variations down to this level are visible on high resolution reciprocal space maps.

Figure 2 shown here is a birefringence micrograph of a high quality synthetic diamond which has been cut and polished on the (110) plane. The scattering from this diamond was studied. The (111) growth sector contains more nitrogen than the (001) and it is zoned into the growth bands seen in the photograph. These bands influence the scattering in two ways. The large, planar growth-sector boundaries give rise to sharp scattering features such as are conspicuous in the reciprocal space map of the scattering around the 004 reflection shown in Figure 3.

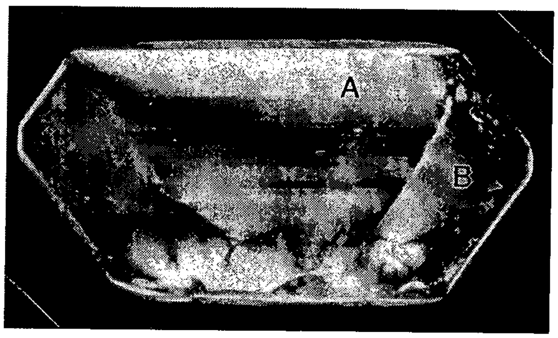

Figure 2. Birefringence micrograph of a synthetic diamond (5 mm x 2.5 mm x 1 mm) showing growth sectors with banding. The (001) growth sector is marked A and the (111) growth sector is marked B.

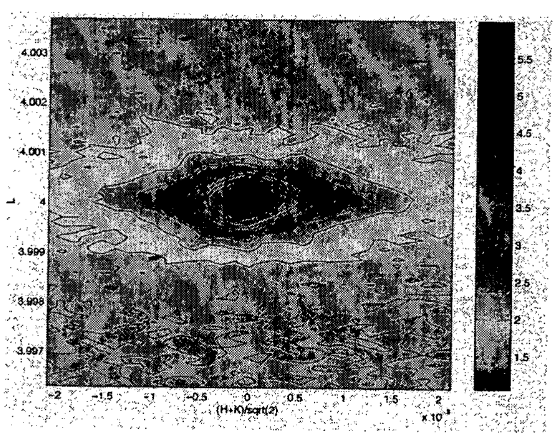

Figure 3. Reciprocal space map of the 004 reflexion from the (111) growth sector of the diamond of Figure 2. The horizontal axis is in the [001] direction, vertical axis in [110]. (See text for description.)

Even at the highest resolution, these features are less than one pixel wide. The general spread of scattering around the relp, which does not have the symmetry of phonon scattering, is a reflection of both angular strain (small, local tilt variations) and linear strain (localised lattice parameter variations). We have found that this spread is generally greater than the resolution function of the diffractometer. From the map, the angular strain is about 60 mdeg and lattice parameter variations about 6 in 10^4. Reciprocal space maps showing a range of asymmetric features were also recorded and will be the subject of further study.

References

[1] *S.G. Clackson, M. Moore, J.C. Walmsley, G.S. Woods, Phil. Mag. B 62 (1990) 115-128.*

[2] *M. Moore, R. Waggett, W. Wierzchowski, A. Makepeace, Diamond & Related Materials 2 (1993) 115-120.*

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Department of Physics
Dr. R. Jones publications in 1991

Up to the index or back to Dr. R. Jones publications in 1992 (17 publications).

Computers Calculate Silicon Surface Structure
G. Srivastava, R. Jones
Physics World March 1991, 28, 1991.

Interaction of Impurities with Dislocation Cores in Silicon
M. Heggie, A. Umerski, R. Jones
Phil. Mag. A 63, 571-84, 1991.

Metastable States in Si:H
R. Jones
Physica B 170, 181-187, 1991.

Localised Vibrational Modes of Hydrogen-impurity complexes in GaAs
P. Briddon, R. Jones
Physica B 170, 413-6, 1991.

A Simple Model for the Growth of Platelets in Diamond
R. Jones, S. Öberg
Proc. of the Diamond Conference Oxford, 1991 p 19.

Theory of the Structure and Dynamics of the C impurity and C-H Complex in GaAs
R. Jones, S. Öberg
Phys. Rev. B 44, 3673-7, 1991-II.

Structure and Dynamics of the DX centre in GaAs:Si
R. Jones, S. Öberg
Phys. Rev. B 44, Rapid Communications, 3407-8, 1991.

Structure and Dynamics of Substitutional Phosphorus in Diamond
R. Jones, S. Öberg
Phil Mag. Lett. 64, 317-9, 1991.

Interaction of Hydrogen with Impurities in Semiconductors
R. Jones, S. Öberg, A. Umerski
Materials Science Forum 83-7, 551-62, 1991.

Theory of Nitrogen and Platelets in Diamond
P. Briddon, R. Jones, M. Heggie
Materials Science Forum 83-7, 457-462, 1991.

Ab initio Calculations of the Structure and Dynamical Properties of Boron Double Acceptors in GaAs
R. Jones, S. Öberg
Semicond. Sci. and Tech. 6, 1093-5, 1991.

Theory of Nitrogen in Diamond: The Substitutional Atom, A centre and the Platelet
P. Briddon, R. Jones, M. Heggie
International Conference on New Diamond Science and Technology ed R. Messier, J. T. Glass, J. E. Butler and R. Roy, Washington, Materials Research Society, Pittsburgh, Pennsylvania, 1991, p 63.

Forward to Dr. R. Jones publications in 1990 (11 publications).

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Journal of Physics: Condensed Matter **12**(49), 10257-10261 (2000)

Small aggregates of interstitials and models for platelets in diamond

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Abstract

By examining the structure of small clusters of self-interstitials in diamond using local-density-functional techniques, we have developed models for the planar defects called platelets. We present the structures, energies and vibrational properties.

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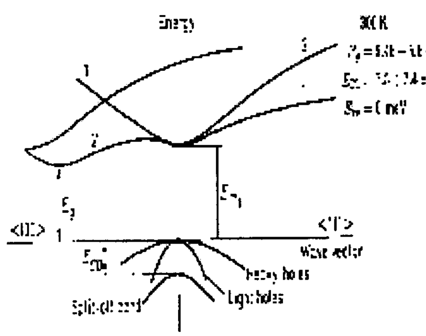
Christopher D. Latham HTML 3.2: [W3C][WDG]

C - Diamond

Band structure and carrier concentration

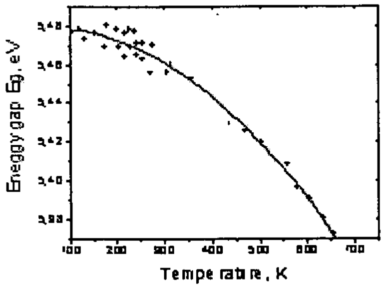
Basic Parameters

Energy gap	5.46-5.6 eV
Energy separation ($E_{\Gamma 1}$)	7.3-7.4 eV
Energy of spin-orbital splitting E_{s0}	0.006 eV
Intrinsic carrier concentration	$\sim 10^{-27}$ cm^{-3}
Intrinsic resistivity	$\geq 10^{42}\,\Omega\cdot$cm
Resistivity of diamonds types I and IIa (usually)	$\sim 10^{16}\,\Omega\cdot$cm
Resistivity of diamonds type IIb	$\sim 1\text{-}10^{3}\,\Omega\cdot$cm
Effective conduction band density of states	$\sim 10^{20}$ cm^{-3}
Effective valence band density of states	$\sim 10^{19}$ cm^{-3}



Band structure and carrier concentration of Diamond. 300 K
E_g=5.46-5.6 eV
$E_{\Gamma 1}$=7.3-7.4 eV
E_{so}=6 meV

Temperature Dependences



Temperature dependence of the energy gap
(Clark et al., 1964)

At 300 K:

$dE_g/dT=-(5.4\pm0.5)\cdot10^{-5}$ eV K^{-1} (Vavilov and Konorova [1976]).

$dE_{\Gamma l}/dT=-6\cdot10^{-4}$ eV K^{-1} (Clark et al. [1964]).

Effective Masses and Density of States

Electrons

The surfaces of equal energy are ellipsoids.

$m_l=1.4m_o$
$m_t=0.36m_o$

Effective mass of density of states in one valley of conduction band
$m_c=(m_l\cdot m_t^2)^{1/3}=0.57m_o$
There are 6 equivalent valleys in the "Si-like" conduction band of diamond.
Effective mass of density of states for all valleys of conduction band $m_{cd}\approx 1.9m_o$
Effective mass of conductivity $m_{cc}=3(1/m_l+ 2/m_t)^{-1}=0.48m_o$

Holes

Cyclotron resonance measurement date (Rauch [1962]):

heavy $m_h= 2.12m_o$
light $m_{lp}= 0.7m_o$
split-off band $m_{so}=1.06m_o$

Effective mass of density of states $m_v=0.8m_o$

There is a considerable uncertainty regarding the density of states effective mass. There is a considerable uncertainty regarding the density of states effective mass. The values as low as $m_v=0.16m_o$ (Kemmey and Wederpohl [1965]) and as high as $m_v=1.1m_o$ (Dean [1965]) have been reported. For estimations, one can use the value of $m_v=0.8m_o$ which is close to $m_v=0.75m_o$ (Collins and Williams [1971]) and $m_v=0.88m_o$ (Prosser

Donors and Acceptors

B (boron):

Boron is a deep acceptor level with activation energy of 0.37 eV. So far semiconductor applications of diamond have been based almost exclusively on boron-doped *p*-type samples (Gildenblat et al. [1991]).

N (nitrogen):

Nitrogen is a most common impurity (donor) in diamond. It is difficult to specify the activation energy since nitrogen can appear as isolated substitutional impurity, simple aggregates or platelets (Stoneham [1992]). In particular, the energy levels of 1.7 eV and 4 eV below the bottom of the conduction band are often ascribed to

nitrogen impurities *(Davies [1977]; Vermeulen and Farer [1975]; Novikov [1987])*.

P (phosphorus):

There are indications that doping with phosphorus results in donor states with activation energies 0.84÷1.16 eV *(Okano et al. [1990])*. Further details are reviewed in *(Gildenblat et al. [1991] and Stoneham [1992])*.

mytrix

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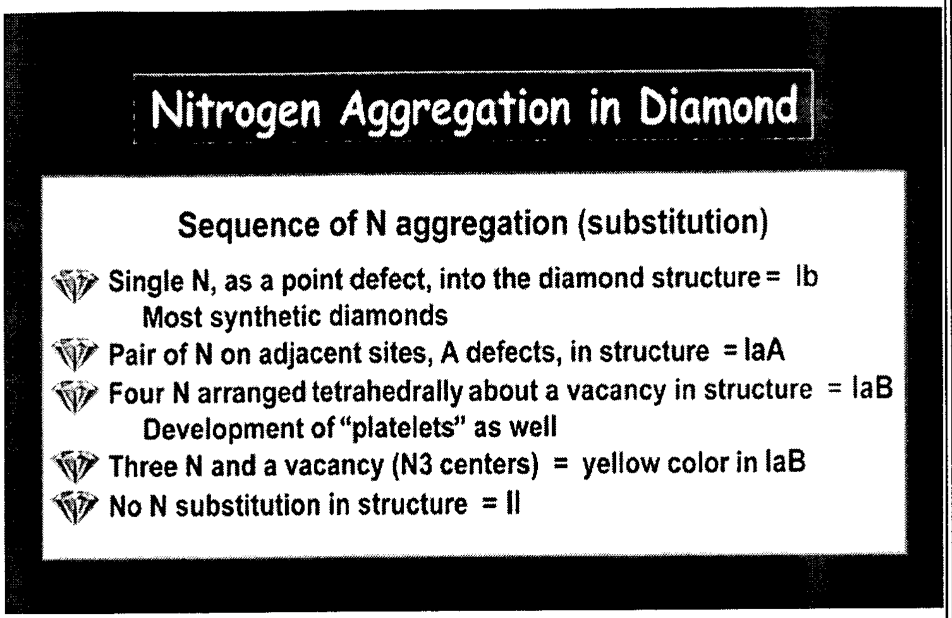

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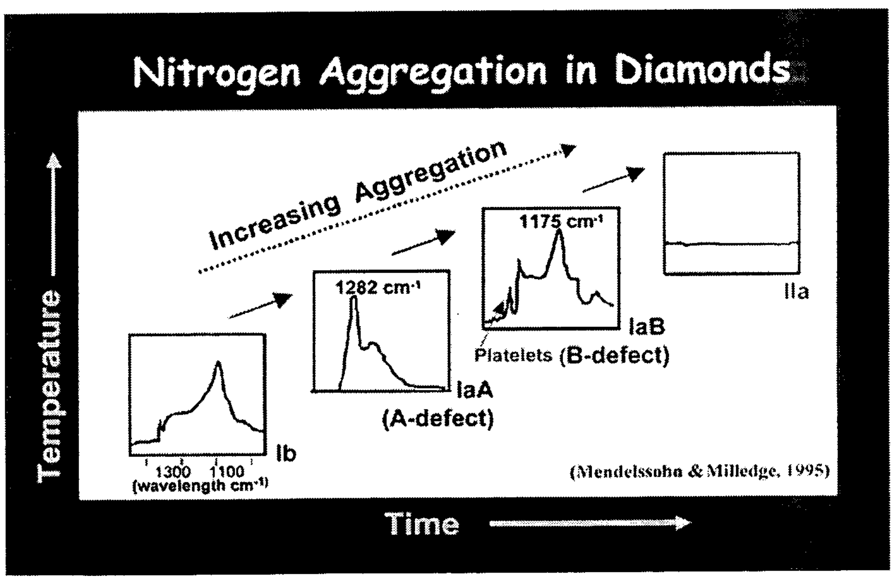
(slide 5/21)



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(slide 6/21)

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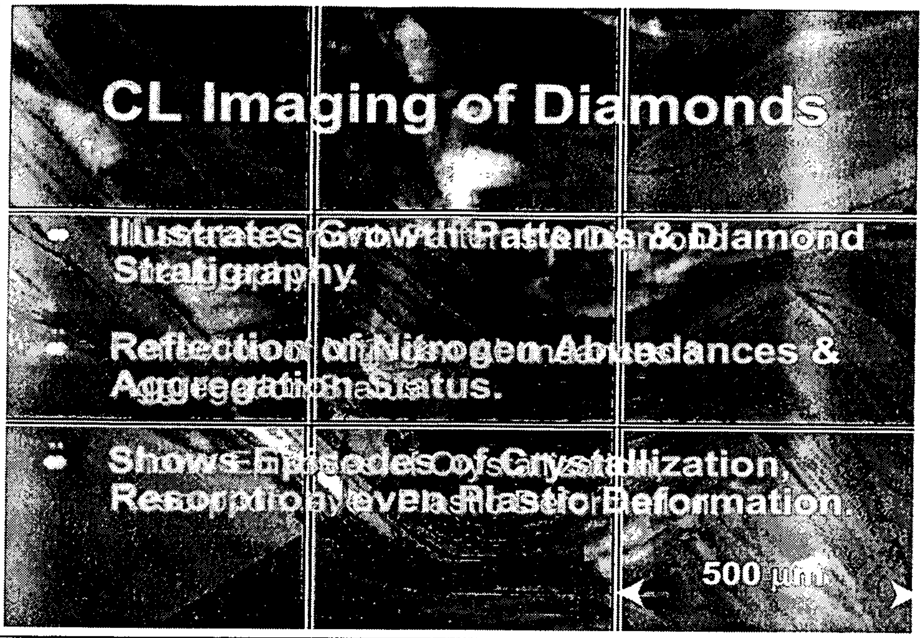

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(slide 7/21)

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Paper for IS&T NIP16 Conference, Vancouver, Canada, Oct. 16-20, 2000 (Final manuscript)

CIE Fundamentals for Color Measurements

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Abstract

The paper first overviews the CIE system of colorimetry, covering CIE 1931 color matching functions, *XYZ* tristimulus values, the *x, y* diagram, the 1976 *u', v'* diagram, and the evolvement of CIELUV and CIELAB color spaces and color difference formulae. The paper reviews the measurement of object colors introducing CIE standard illuminants and the CIE terminology for color and reflectance measurements, then the measurement of light-source colors (including displays) with calculation of correlated color temperature and color rendering indices. The paper also discusses practical aspects of color measurements for imaging applications using spectroreflectometers, spectroradiometers, and tristimulus colorimeters. Overview is given for calibration and verification of instruments' accuracy, spectral irradiance and reflectance standards (available from national laboratories), and uncertainty components.

Introduction

The term *color* is used with different meanings in different technologies. To lamp engineers, color refers to a property of light sources. To graphics art engineers, color is a property of an object's surface (under a given illumination). In each case, color must be physically measured in order to record it and reproduce the same color. The perception of color is a psychophysical phenomenon, and the measurement of color must be defined in such a way that the results correlate accurately with what the visual sensation of color is to a normal human observer. *Colorimetry* is the science and technology used to quantify and describe physically the human color perception. The basis for colorimetry was established by CIE (Commission Internationale de l clairage) in 1931 based on visual experiments. Even though limitations are well recognized, the CIE system of colorimetry remains the only internationally agreed metric for color measurement. All the official color-related international standards and specifications use the CIE System. The CIE system works well in most cases, but one should know the assumptions and limitations in visual conditions where the CIE system is defined. In this paper, the CIE system of colorimetry is briefly overviewed, and then practical aspects of color measurements and instruments – spectroreflectometers, spectroradiometers, and colorimeters – are discussed, with a focus on the calibration methods and standards. Uncertainty components and correction for errors are also discussed. For further details in colorimetry and color science, refer to official CIE publications [1-3] and many other appropriate references [4].

CIE System of Colorimetry

History and Basis

By the early 19th century, it became known that there were three types of cones in the eyes to sense colors. It was also known that two light stimuli having different spectra could produce the same color (*metamerism*). It was inferred that each cone had spectral sensitivities corresponding to R, G, B (*Trichromatic Theory*, Young, 1800's) or sensitivities corresponding to opponent colors, W/Bk, R/G, and Y/B (*Opponent Theory*, Hering, late 1800's). The spectral sensitivities of the cones were yet to be known at that time, but a color could be matched by combination of three primaries, which could be used to specify color (Maxwell, 1860's).

Around 1930, Wright and Guild made independent visual experiments to derive color matching functions using three R/G/B primaries, the results of which became the basis of the CIE colorimetry system. Observers viewed a 2° circular split field and their task was to adjust the three primaries so that their mixture visually matched the visible spectrum presented sequentially. Fig. 1 shows the results of this experiment using a set of primaries at 435.8 nm, 546.1 nm, and 700 nm. This is the plot of the relative intensities of R,G,B primaries (white-balanced to equal energy white) that matched monochromatic stimulus at each wavelength. The minus value means that one of the primary colors had to be added to the monochromatic stimulus to make the match. In 1931, the CIE adopted these results as the standardized RGB color matching functions denoted as $\bar{r}(\lambda), \bar{g}(\lambda), \bar{b}(\lambda)$. Then still in 1931, the CIE transformed the RGB color matching functions to a new set of primaries, XYZ, to eliminate negative values and with the $\bar{g}(\lambda)$ function set to

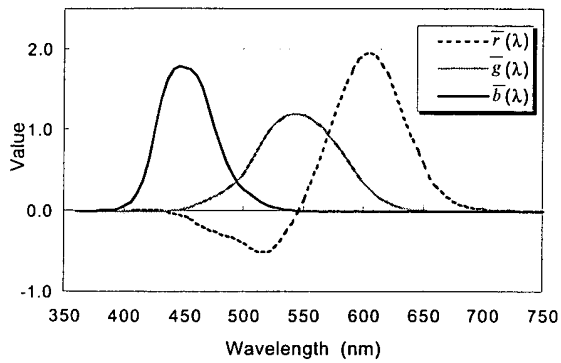


Figure 1 – CIE 1931 RGB color matching functions using primaries at 435.8 nm, 546.1 nm, and 700 nm.

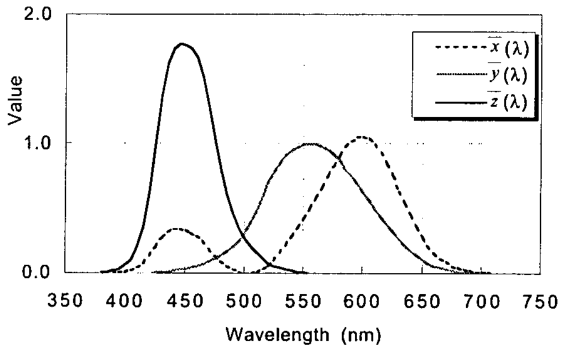


Figure 2 – CIE 1931 XYZ color matching functions.

be equal to the 1924 CIE spectral luminous efficiency function, $V(\lambda)$. This is simply a linear transformation from the RGB color matching functions, and the resulting functions, shown in Fig. 2, are called the *CIE 1931 XYZ color matching functions* denoted as $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$. There are two important assumptions in these color matching functions: First, rod intrusion is excluded, thus it applies only to narrow field-of-view (2°). Second, additivity of light stimuli (*Grassmann's Law*) is assumed. The ideal observer whose color-matching properties correspond to the color matching functions $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$ with the 2° field of view and satisfying the Grassmann's Law is called the *CIE 1931 standard colorimetric observer*. Practically, this observer can be used for field-of-view of up to 4°. In 1964, the CIE defined a second set of standard color matching functions for a 10° field-of-view, denoted as $\bar{x}_{10}(\lambda), \bar{y}_{10}(\lambda), \bar{z}_{10}(\lambda)$, to supplement those of the 1931 standard observer. This is called the *CIE 1964 supplementary standard colorimetric observer*, and can be used for a field of view greater than 4°.

Tristimulus Value

By using the color matching functions, light stimuli having any spectral power distribution can be specified for color by three values:

$$X = k\int_{\lambda}\Phi(\lambda)\bar{x}(\lambda)\mathrm{d}\lambda$$
$$Y = k\int_{\lambda}\Phi(\lambda)\bar{y}(\lambda)\mathrm{d}\lambda \qquad (1)$$
$$Z = k\int_{\lambda}\Phi(\lambda)\bar{z}(\lambda)\mathrm{d}\lambda,$$

where $\Phi(\lambda)$ is the spectral distribution of light stimulus and k is a normalizing constant. These integrated values are called *Tristimulus values*. For light sources and displays, $\Phi(\lambda)$ is given in quantities such as spectral irradiance and spectral radiance. If $\Phi(\lambda)$ is given in an absolute unit and k=683 lm/W is chosen, Y yields an absolute photometric quantity such as illuminance or luminance.

For object colors, $\Phi(\lambda)$ is given by

$$\Phi(\lambda) = E(\lambda)\cdot R(\lambda), \qquad (2)$$

where $R(\lambda)$ is the spectral reflectance or radiance factor of the object, $E(\lambda)$ is the (relative) spectral irradiance of the illumination, and

$$k = 100 / \int_{\lambda} E(\lambda)\bar{y}(\lambda)\mathrm{d}\lambda. \qquad (3)$$

Actual integration can be carried out by numerical summation of spectral data.

Chromaticity Diagrams

By projecting the tristimulus values on to the unit plane (X+Y+Z=1), color can be expressed in a two dimensional plane. Such a unit plane is known as the chromaticity diagram. The color can be specified by the chromaticity coordinates (x, y) defined by

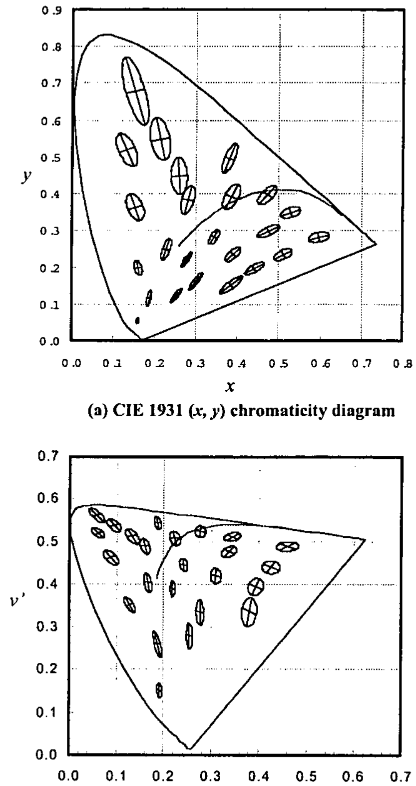
$$x = \frac{X}{X+Y+Z}; \quad y = \frac{Y}{X+Y+Z}. \qquad (4)$$

The diagram using the chromaticity coordinates (x, y) is referred to as the *CIE 1931 chromaticity diagram*, or the *CIE (x, y) chromaticity diagram*.

The (x, y) chromaticity diagram is very non-uniform in terms of color difference. The minimum perceivable color differences in the CIE (x, y) diagram, known as *MacAdam ellipses*, are shown in Fig. 3(a). To improve this, in 1960, CIE defined an improved diagram – *CIE 1960 (u, v) chromaticity diagram* (now deprecated), and in 1976, a further improved diagram – *CIE 1976 uniform chromaticity scale (UCS) diagram*, with its chromaticity coordinate (u', v') given by

$$u' = \frac{4X}{X+15Y+3Z}; \quad v' = \frac{9Y}{X+15Y+3Z}. \qquad (5)$$

The 1976 (u', v') chromaticity diagram is significantly more uniform than the (x, y) diagram, yet it is still far from perfect as shown in Fig. 3 (b).



(a) CIE 1931 (x, y) chromaticity diagram

(b) CIE 1976 (u',v') chromaticity diagram

Figure 3 – MacAdam Ellipses in CIE 1931(x, y) diagram and the CIE 1976 $(u'v')$ diagram. The ellipses are plotted 10 times their actual size.

Uniform Color Spaces and color difference formulae

Three attributes of color, are hue, chroma (saturation), and lightness, and are expressed in a three dimensional space. In the chromaticity diagrams as mentioned above, lightness is missing, and the hue and chroma are laid out very nonlinearly. To allow accurate specification of object colors and color differences, CIE recommended three-dimensional uniform color spaces – CIELAB and CIELUV in 1976. Since the equations are long, they are omitted here. These are called the *CIE 1976 ($L^*a^*b^*$) color space* or *CIELAB color space*, and the other, *CIE 1976 ($L^*u^*v^*$) color space* or *CIELUV color space*, and have similar structures as the Munsell color solid. In imaging applications, CIELAB space is commonly used. In CIELAB space, L^* shows the lightness, and (a^*, b^*) the color as shown in Fig. 4, The coordinate (L^*,a^*,b^*) is calculated from the (X,Y,Z) of the given light stimulus and (X_n,Y_n,Z_n) of the white point. Therefore, the CIELAB space has a function of correcting for chromatic adaptation to the white point, and is intended for object color and displays. The color difference

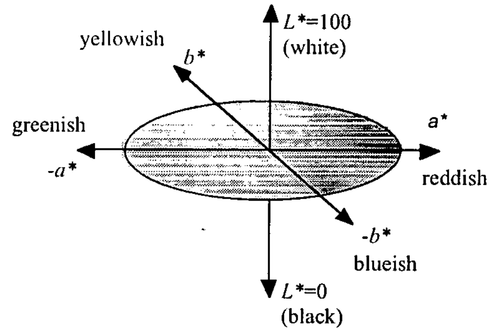


Figure 4 – CIELAB color space.

in the CIELAB space is calculated as the Euclidean distance between the points in this three-dimensional space, and is given by,

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}. \qquad (6)$$

This equation is called the *CIE 1976 ($L^*a^*b^*$) color difference formula*. The chroma C^*_{ab} and the hue angle h_{ab} are also calculated from *($L^*a^*b^*$)* by

$$C^*_{ab} = (a^{*2} + b^{*2})^{1/2} \qquad (7)$$

$$h_{ab} = \tan^{-1}(b^*/a^*). \qquad (8)$$

The CIELUV space is defined in a similar manner, and the coordinate (L^*,u^*,v^*) is calculated from the Y and (u',v') of the given light stimulus and the white point. Refer to references 1 and 4 for the details.

While the color difference ΔE^*_{ab} is widely used, its chroma scale is known to be fairly nonlinear. For more accurate color difference evaluations, CIE recommended an improved industrial color difference formula in 1994 - *CIE94 Formula*[5]. The color difference ΔE^*_{94} is calculated from ΔL^*, ΔC^*_{ab}, and ΔH^*_{ab} of the CIELAB formula. Another improved formula, *the CMC Colour Difference Formula*, is mainly used in textile industry [6]. Further improved color difference formulae are being investigated by CIE (TC1-55).

Correlated Color Temperature

The color of light sources are measured and expressed by the resultant chromaticity coordinates (x,y) or (u',v'). However, it is difficult to relate these values immediately to particular colors. For such practical purposes, the color of "white light" can be expressed by *correlated color temperature (CCT)* in the unit Kelvin [K]. The CCT is defined as the temperature of the Planckian radiator whose perceived color most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions [7]. For example, 2800 K is immediately associated with the warm color of incandescent lamps, and 9000 K the bluish white from a CRT. According to this definition, CCT can be calculated using one of the chromaticity diagrams.

Due to the long tradition, CIE still recommends to calculate CCT using the 1960 (u,v) chromaticity diagram (now deprecated) [1]. From (u',v') coordinates, (u,v) can be obtained by $u=u'$, $v=2v'/3$. On the (u,v) diagram, find the point on the Planckian locus that is at the shortest distance from the given chromaticity point. CCT is the temperature of the Planck's radiation at that point. A practical way of computing CCT is available [8].

Color Rendering Index

For lamps in lighting applications, it is important to evaluate how well a given illumination can render colors of objects in the illuminated scene. The CIE defined the *color rendering index (CRI)* for the first time in 1965. Going through minor revisions, the CIE recommendation[9] has been in wide use mainly by lighting industry. The procedure of calculation is first to calculate the color differences ΔE_i (on the 1964 $W^*U^*V^*$ uniform color space – now obsolete) of selected 14 Munsell samples between the conditions when illuminated by a reference illuminant and when illuminated by the given illumination. The process incorporates the von Kries chromatic adaptation transformation. Then the *Special Color Rendering Index* R_i for each color sample is calculated by

$$R_i = 100 - 4.6\,\Delta E_i. \tag{9}$$

This gives an indication of color rendering for each particular color. The *General Color Rendering Index*, R_a, is given as the average of the first eight color samples (medium saturation). With the maximum value being 100, R_a gives a scale that matches well with the visual impression of color rendering. For example, lamps having R_a values greater than 80 may be considered suitable for interior lighting, and R_a greater than 90 for visual inspection purposes.

Standard Illuminants

The colors of objects change depending on the spectrum of illumination. Thus, there is a need to specify the illumination for any object color specification. For this purpose, colorimetric illuminants are standardized by CIE and ISO [1,2]. *CIE Standard Illuminant A* (representative of tungsten-filament lighting with a color temperature of 2856 K) and *CIE Standard Illuminant D65* (representative of average daylight with a CCT of 6500 K) are the two primary standard illuminants [2]. It is recommended that either of these illuminants be used in all applications. However, other phases of daylight illuminant are already widely used in specific application areas, and CIE also defines D50, D55 and D75 [1]. Equations are available to obtain the data table for Illuminant A and any phase of D illuminant. Even though no longer recommended for use, Illuminant B was intended to represent direct sun light with a CCT of ~4900 K, and Illuminant C to represent average daylight with a CCT of ~6800 K and to be realized by a tungsten source combined with a prescribed liquid filter.

Measurement of Object Color

Terminology of reflectance measurement

Object color, in most cases, is determined by spectral reflectance measurements. The terminology for reflectance measurements is often confused and misused by the imaging community. Some important terms are reviewed here according to Ref. 7.

Reflectance is the ratio of the reflected radiant or luminous flux to the incident flux in the given conditions of spectral composition, polarization, and geometrical distribution. The geometrical conditions are very important for correctly describing and measuring reflectance, and can lead to confusion regarding reflectance measurements.

Perfect Reflecting Diffuser is an ideal isotropic diffuser with a reflectance equal to 1.

Reflectance Factor is the ratio of the radiant or luminous flux reflected in the direction delimited by the given cone to that reflected in the same direction by a perfect reflecting diffuser identically irradiated or illuminated.

Radiance Factor is the ratio of the radiance of a surface element in a given direction to that of a perfect reflecting diffuser identically irradiated.

Radiance Coefficient is the ratio of the radiance of the surface element in the given direction to the irradiance on the medium.

There are several important implications that follow from the above definitions. "Factor" in these terms means with respect to a perfect reflecting diffuser, and therefore can be greater than one. Reflectance, on the other hand, can never be greater than one, and is often used descriptively to represent all of these reflectance-related quantities. Reflectance factor is defined in terms of a cone, while radiance factor is defined only in terms of a direction. Therefore, if the solid angle of the cone approaches zero, the reflectance factor approaches the radiance factor for the same conditions of irradiation. If the solid angle of the cone approaches 2π sr, the reflectance factor approaches the reflectance for the same conditions of irradiation. Finally, radiance coefficient is similar to the *bi-directional reflectance distribution function (BRDF)* except that the latter is defined for directional incident flux.

Illuminating and viewing conditions

Geometry is one of the most important conditions to specify in reflectance colorimetry. For the colorimetry of objects, CIE recommends the use of one of four standard geometries – 45°/normal (45/0), normal/45° (0/45), diffuse/normal (d/0), and normal/diffuse (0/d). The details on this subject are covered by the paper by Danny Rich [10].

Reflectance standards

Most spectroreflectometers are calibrated using white reflectance standards for one of the geometries listed above. *Spectral radiance factor standards* are needed for the 45/0,

0/45, and d/0 geometries, while *diffuse spectral reflectance standards* are needed for the 0/d geometry. Highly diffuse white materials such as pressed or sintered polytetrafluoroethylene (PTFE) are used for such standards. Because absolute measurements of radiance or reflectance factors are very difficult, calibrated standards are provided by national metrology laboratories [11, 12], and industrial measurements are normally made with traceability to these standards. Since a perfect reflecting diffuser does not exist, the radiance factor is calibrated by absolute measurements of the radiance coefficient. The radiance factor is then obtained from the radiance coefficient by multiplying by the constant π.

The reflectance characteristics of even the most diffuse materials are sensitive to the illumination and viewing angles. An example for the measured spectral radiance factor of a pressed PTFE sample is shown in Fig. 5.

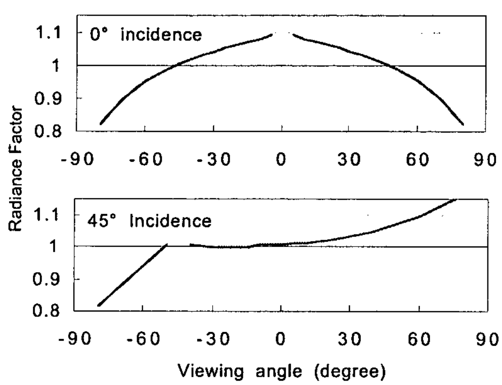


Figure 5 – Radiance factor of pressed PTFE as a function of viewing angle at a wavelength of 555 nm.

Measurement instruments for object color

Spectroreflectometers are commonly used for object color measurements. These instruments measure the spectral reflectance of a test sample under a given geometrical condition, and most are calibrated by a reference standard traceable to a national metrology laboratory. Thus, their measurement uncertainty first depends upon the uncertainty of the reference standard. Uncertainties also arise from the characteristics of the spectroreflectometer. Effects contributing to the uncertainty include wavelength error, detector nonlinearity, stray light, bandwidth, the geometrical conditions for both illumination and viewing, and measurement noise. The effect of bandwidth can be serious for bandwidths greater than 10 nm. For example, a 20 nm bandwidth can cause errors of as much as two to three CIELAB units for saturated colors. An effective correction method is available [13]. Recommendations for standard methods to characterize spectroreflectometers are being developed by the CIE TC2-28 committee. Finally, the uncertainty can also depend upon the characteristics of the test sample. For example, saturated color samples tend to have larger errors.

In order to verify stated measurement uncertainties for spectrophotometers, calibrated color standards are used. Ceramic tiles of various colors manufactured by the British Ceramic Research Association (BCRA) are available from the National Physical Laboratory (NPL), UK and will be available from the National Institute of Standards and Technology (NIST), USA.

For measurements of small color differences, tristimulus colorimeters are used because of their benefits of high speed and low cost. The uncertainty of tristimulus colorimeters is limited, however, due to the mismatch of the illumination to the CIE illuminants and of the spectral response of the detectors to the CIE color matching functions. Thus, they are not suitable for absolute color measurements over a wide range of colors [14].

A number of recommendations on spectral reflectance and color measurements are available from the American Society for Testing and Materials (ASTM) [15].

Measurement of Light Source Color

The measurement of light source color is represented by measurement of lamps, LEDs, and displays. Both spectroradiometers and tristimulus colorimeters are widely used.

Measurement instruments for light source color

Spectroradiometers are normally designed to measure either *spectral irradiance* (unit: W m^{-2} nm^{-1}) or *spectral radiance* (unit: W sr^{-1} m^{-2} nm^{-1}). The former is equipped with a diffuser or a small integrating sphere as input optics, and the latter equipped with imaging optics. For example, lamps are normally measured for spectral irradiance and displays are measured for spectral radiance to obtain colors. There are two types of spectroradiometers; mechanical scanning type and diode-array type. Generally, the former is more accurate but slow, and the latter is fast but less accurate. Spectroradiometers are calibrated against spectral irradiance or radiance standards traceable to national standards [16]. Thus, their measurement uncertainty first depends on that of the reference standard. Then, like spectroreflectometers, there are many other uncertainty components including wavelength error, detector nonlinearity, stray light of monochromator, bandwidth, measurement noise, etc. The errors vary depending on the spectrum of the source measured. Even if the instrument's specification shows a low uncertainty for a tungsten source (normally a calibration source), the instrument's uncertainty for other colors can be much larger. For example, typical diode-array spectroradiometers exhibit errors of up to 0.005 in x, y for various display colors while they are specified for an uncertainty of ~0.001 in x, y for CIE Illuminant A. For applications where highest accuracy is required, it is necessary to calibrate the instruments for various actual colors to be measured. For color measuring instruments for displays, such a calibration facility and services are available [17].

Tristimulus colorimeters are also widely used for colorimetry of lamps and displays. While they have benefits of low cost and high speed, errors due to spectral mismatch are inevitable and their uncertainty for measurement tend to be higher than spectroradiometers. To improve accuracy in display measurements, effective correction techniques are available[18, 19].

Uncertainty of measurements

Uncertainty of measurement is an estimate of the range of values within which the true value lies. When making colorimetric and photometric measurements, it is important to know the uncertainty of the results. The uncertainty in a measurement depends not only on that of the measurement instruments but also on the measurement conditions. The measurement uncertainty must be stated for official exchange of measurement results, and it must follow the international recommendations[20]. The term *accuracy* is no longer recommended to specify the values of uncertainty. For industrial measurements, it is now recommended to use an *expanded uncertainty* with a coverage factor k=2. See Ref. 20 for the details.

Conclusion

An overview has been given for the fundamentals of the CIE colorimetry system and practical issues in measurements of object color and light-source color. When making measurements, one should be aware of the uncertainty of the measurement instruments and uncertainty components arising from the measurement conditions. Refer to the given references for the details in the subjects covered in this paper.

Acknowledgement

The author thanks Danny Rich of Sun Chemical, Edward Early and Maria Nadal of NIST for their providing useful information and comments.

References

1. CIE Publ. No.15.2, *Colorimetry*, Second Edition (1986). (No. 15.3 to be published)
2. ISO/CIE10526-1991, CIE standard colorimetric illuminants (1991).
3. ISO/CIE10527-1991, CIE standard colorimetric observers (1991).
4. For example, G. Wyszecki, and W. S. Stiles, *Color Science: Concepts and Methods, Quantitative Data and Formulae*, John Wiley and Sons, Inc., New York (1982).
5. CIE Publ. No. 116, Industrial colour difference evaluation (1995).
6. R. McDonald, Acceptability and Perceptibility Decisions Using the CMC Colour Difference Formula, Textile Chemist and Colorists **20**-6, pp. 31-37(1988) and Errata, Vol. 20, No. 8, p.10 (1988).
7. CIE Publ. No. 17.4/IEC Pub. 50(845) International Lighting Vocabulary (1989).
8. R. Robertson, Computation of correlated color temperature and distribution temperature, J. Opt. Soc. Am. **58**, 1528-1535 (1968).
9. CIE Publ. No. 13.3, Method of Measuring and Specifying Colour Rendering Properties of Light Sources (1995).
10. D. Rich, Advances in the Geometric Specifications of Instruments for the Measurement of Color and Color-Differences, Proc., IS&T NIP16 (2000).
11. For example, R. Barnes, E. Early, and A. C. Parr, NIST Special Publication 250-48 Spectral Reflectance (1998).
12. CIE Publ. No.44, Absolute Methods for Reflection Measurement (1979, reprint in 1990).
13. ASTM E308-95, Standard Practice for Computing the Colors of Objects by Using the CIE System (1995).
14. ASTM E1347-90, Standard Test Method for Color and Color-Diffrence Measurement by Tristimulus Colorimetry (1990).
15. ASTM Standards on Color and Appearance Measurement, Sixth Edition, ASTM, West Conshohoken, PA (2000).
16. For example, J. Walker, R. Saunders, J. Jackson, and D. McSparon, NIST Special Publication 250-20 Spectral Irradiance Calibrations (1987).
17. S. Brown and Y. Ohno, NIST Calibration Facility for Display Colorimeters, Proc., IS&T/SPIE 11th Intn. Symposium, Electronic Imaging '99, San Jose (1999).
18. ASTM E 1455-96, Standard Practice for Obtaining Colorimetric Data from a Visual Display Unit Using Tristimulus Colorimeters (1996).
19. Y. Ohno and S. Brown, Four-Color Matrix Method for Correction of Tristimulus Colorimeters - Part 2, Proc., IS&T Sixth Color Imaging Conference (1998).
20. ISO, Guide to the Expression of Uncertainty in Measurement, a joint publication by BIPM, IEC, ISO, IFCC, IUPAC, IUPAP, OIML, First edition (1993).

Biography

Yoshi Ohno received a Ph.D. in engineering from Kyoto University, Kyoto, Japan in 1993. He started his career in photometry and colorimetry at Matsushita Electric Ind. Co. in Japan in early 1980s, and immigrated to the U.S. in 1992 to be employed by NIST. He is currently the project leader for Photometry at Optical Technology Division, NIST, and recently led a project for colorimetry of displays. He serves as the Secretary of CIE Division 2, and chairs two CIE technical committees in photometry. He is a member of CIE TC1-48 (revision of CIE 15.2) and IEC TC100/TA2. Email: ohno@nist.gov

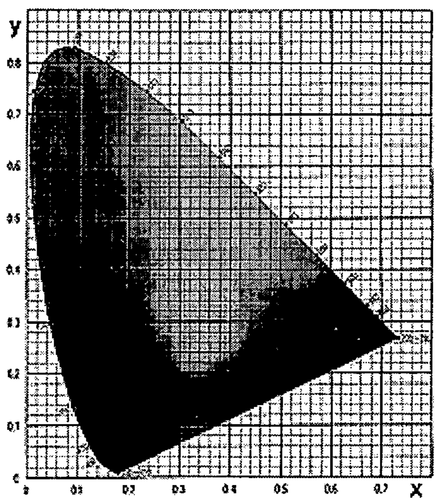
SUPPLEMENTAL READINGS
useful information about related subjects

COLOR GAMUTS

Starting With XYZ

The creation of a global color standard embracing the most important color gamuts and enabling consistant color communications is vital for the growth of color reproduction. The CIE, the Commission Internationale de l'Eclairage, plays a leading role in the definition of color systems.

In 1931 the CIE developed the XYZ color system, also called the "norm color system." This system is often represented as a two-dimensional graphic which more or less corresponds to the shape of a sail.



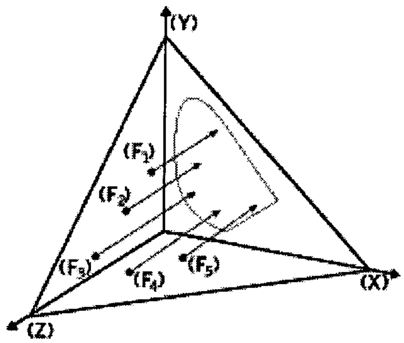
The red components of a color are tallied along the x (horizontal) axis of the coordinate plane and the green components along the y (vertical) axis. In this way every color can be assigned a particular point on the coordinate plane. As you can see, colors on the left tend toward gray, which means that their spectral purity is decreased.

What is not taken into consideration in the above model is the variant of brightness. If it were, the sail-like figure would look like a flat sack. More on that later.

This Isn't Rocket Science...Really!

The CIE color standard is based on imaginary primary colors XYZ -- which don't exist physically. They are purely theoretical and independent of device-dependent color gamuts such as RGB or CMYK. These virtual primary colors have, however, been selected so that all colors which can be perceived by the human eye lie within their color space.

The XYZ system is based on the response curves of the eye's three color receptors. Since these differ slightly from person to person, CIE has defined a "standard observer" whose spectral response corresponds more or less to the average response of the population. This objectifies the colorimetric determination of colors.



The three primary colors of the CIE XYZ reference system call for a spatial model with coordinates (X), (Y) and (Z), which is drawn as a chromaticity triangle. To arrive at a two-dimensional diagram (the sail shape), this chromaticity triangle is projected into the red-green plane.

This is only meaningful, however, if appropriate standardization is performed at the same time which allows the lost value (Z) to be read from the new two-dimensional model. This is achieved by introducing the chromaticity coordinates x, y and z. They are defined as follows:

- $x = X / (X + Y + Z)$
- $y = Y / (X + Y + Z)$
- $z = Z / (X + Y + Z)$

where $x + y + z = 1$

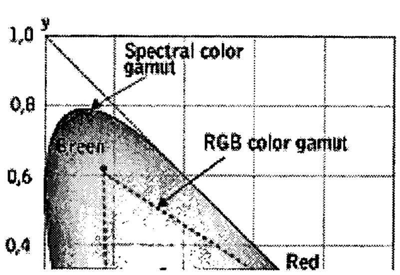
The value z of any desired color can be obtained by subtracting the chromaticity coordinates x and y from 1:

$1 - x - y = z$

However, the CIE chromaticity diagram does have a few drawbacks:

- Brightness is difficult to include
- There is a discrepancy between perceived color differences and the actual spacing of color in the system.

Adding Brightness to Color



A color is not defined fully by its chromaticity (x and y). A brightness coefficient also needs to be specified. The eye response curve for green is standardized in the XYZ system so that it

simultaneously reflects the sensation of brightness. That makes it identical to the V (l) curve. A color is only described in full if it contains the values x and y plus the brightness coefficient Y.

In the standard color triangle, the right-angled chromaticity triangle drawn between zero, x = 1 and y =1 represents the boundaries of this reference system. Chromaticities cannot lie outside the triangle. The closed curve section represents the position of the spectral colors.

While it is possible to define colors between the triangle and spectral color gamut, they are only realized on virtual basis, i.e. not physically. The primary colors RGB of a reproduction device -- such as a color monitor -- form a triangle within the spectral color gamut. That triangle represents a smaller color gamut with the achromatic point more or less in the center.

Exactly!

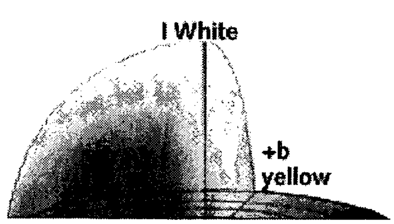
The introduction of the CIE color system made it possible to transform color determination from a quality-describing process -- "I want a bright red -- into a process which can be expressed in exact quantitative and numerical terms.

In addition to the quantitative judgement it allows, the CIE color space permits the results of additive color mixing to be presented in simple form. The results always lie on straight lines between the colors being mixed. The CIE standard also allows any desired color transformations from one color gamut to another. For example, the transformation of a given color from the RGB color gamut of a monitor to the CMYK gamut of a printing process is facilitated by this standard.

Perceived Color Differences

As mentioned, one problem with the XYZ color system is that colorimetric distances between the individual colors don't correspond to perceived color differences.

For example, in the figure above, a difference between green and greenish-yellow is relatively large, whereas the distance distinguishing blue and red is quite small.



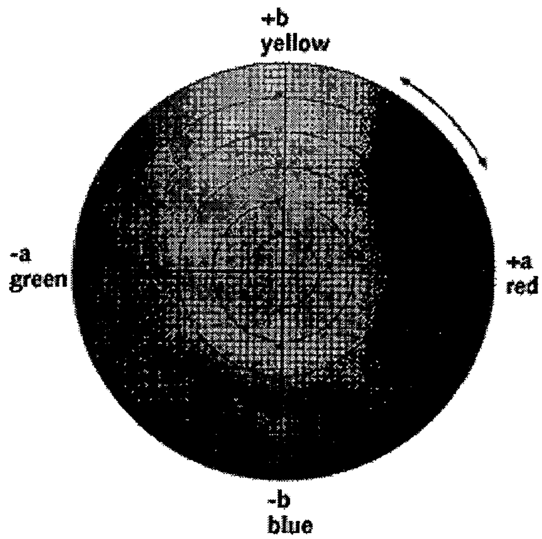
CIELAB: CIE solved this problem in 1976 with the development of the Lab color space. A three-dimensional color space

was the result.

In this model, perceived color differences correspond to measured linear colormetric distances. The "a" axis extends from green (-a) to red (+a) and the "b" axis from blue (-b) to yellow (+b). The brightness (L) increases from the bottom to the top of the 3-dimensional model.

With CIELAB what you see is what you get -- and that's exactly what you want in color management.

CIELAB and Brightness



A horizontal cross-section of the CIELAB model reveals a plane which depicts all values of the same brightness. That means every color can be named exactly using its specific a, b values together with its brightness, L.

The important aspect of this color space is that it is device independent -- completely independent of weather, mood or scanner or color copier -- and is therefore objective.

Thus, the same combination of a, b, and L values always refers to the same color...no matter what.

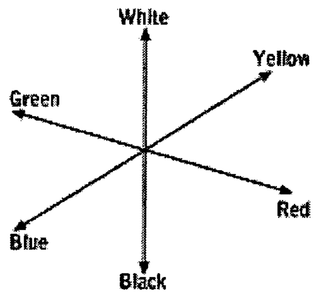
CIELAB Color Space

Color vision is complex. While the retina at first registers three color stimuli -- relating to red, green and blue light rays -- it is not until a further processing stage that three sensations are generated:

- a red-green sensation
- a yellow-blue sensation
- a brightness sensation

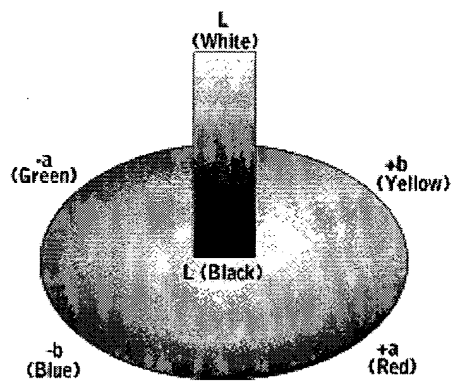
These sensations are used to develop a system known as the complementary color system. It is based on the differences of three

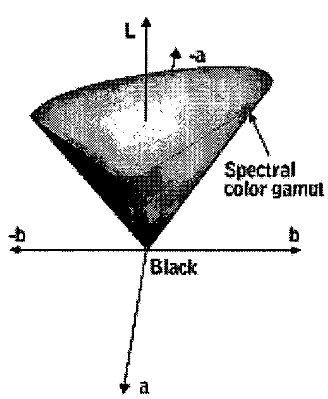
elementary color pairs: red-green, yellow-blue and black-white.



You know from experience that red can never contain green components, blue cannot contain yellow components and white never contains black. It follows that in a reference system which has been designed correctly -- in visual sensation terms -- the achromatic brightness information and the color information should be separated not only quantitatively but qualitatively.

Hue and chroma are defined by the coordinates a and b which can have both positive and negative values. As with the standard color triangle, this color system represents all conceivable colors.



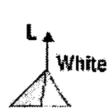


Thus, numerical values for chroma and hue are derived from a and b:

Hue: h = arctan (b/a)
(This corresponds to the angle between the color vector and the +a axis)
Chroma: c = (a2 + b2)1/2
(This corresponds to the distance between the color locus and the mid-point)
Brightness: L
(The third characteristic is represented vertically by means of a brightness scale, designated L, with scale values ranging from 0 for black to 100 for white)

A color gamut in CIELAB appears to the right (in idealized form, of course)

For the sake of clarity, the different brightnesses of the spectral color curve are not shown in their entirety. The model is delimited at the top by a horizontal section. On the outer surface lie all colors of maximum chroma. As colors become darker they lose chroma. This is logical considering that, when the minimum brightness value is reached, every color becomes black and the chroma value is zero.



Thus, a color gamut based on real colors

would actually look like as you see to the immediate right. And, as we understand the way color exists in the real world, two things are clear:

- As the brightness increases or decreases, the chroma reduces to zero when white or black is reached.
- In contrast to the CIE color triangle, the connecting lines between the primary colors are not straight.

The reason for this lies in the visual equispacing of colors in CIELAB. This has been achieved through a non-linear transformation of the XYZ values into CIELAB values.

The formulas for the transformation of XYZ to CIELAB are based on:

- L = 116 Y1/3 - 16
- a = 500 (X1/3 - Y1/3)
- b = 200 (Y1/3 - Z1/3),

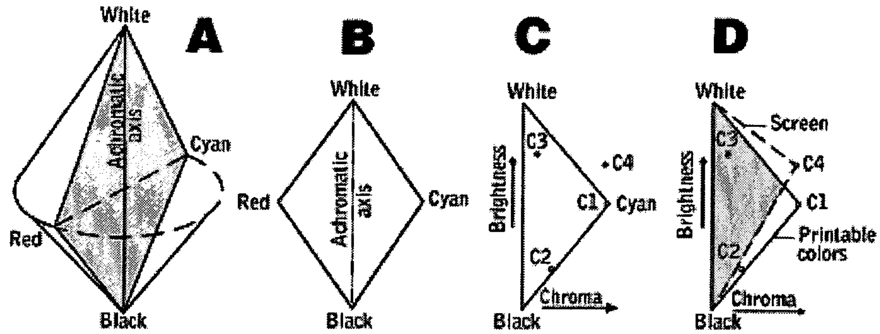
with X, Y and Z standardized to 1.

Advantages of CIELAB in Color Reproduction

The CIELAB color space has many advantages. Above all, it is not dependent on any particular device independent so you can set colors as you perceive them when operating a reproduction system.

CIELAB color space -- like the XYZ color space -- is able to represent all real color gamuts as subsets.

Assume a reproduction system which is based on the RGB color space. The RGB color values need to be converted to CMYK color values for the printing process. The two color spaces coincide in neither size nor location. Due to the fact that the system has RGB as its reference system, it follows that colors of the CMYK color space which cannot be represented in RGB cannot be printed in CMYK. RGB acts as a restriction to CMYK. For example, chromatic cyan cannot be represented on the RGB monitor and, under such circumstances, becomes a non-reproducible color.



To illustrate, look at the cross-section of a stylized color gamut (figure A). In the next illustration (figure B), you now see the cyan-red plane. The problem can be shown in simpler form if only one of the two planes is observed -- in this case the cyan plane (figure C).

The colors depicted show:

- C1 -- cyan with maximum chroma
- C2 -- cyan with the highest possible chroma for this brightness value
- C3 -- a pale near-achromatic cyan
- C4 -- a cyan which lies outside the color space

In the diagram, all the colors have the same hue: cyan. It is possible to reproduce them all -- except C4 which lies outside the color space. If the printable colors are included, the two color spaces are not identical (figure D).

The fact that the two color gamuts overlap means that only the colors in a common subset (shaded area) can be reproduced both on the monitor and in print.

In a device-dependent reference system like RGB or CMYK, colors lying outside their reference system cannot be reproduced even if they are present in the target color gamut. The advantage of global reference systems such as the XYZ or CIELAB, which are unrestricted, become obvious through this example.

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Understanding Color Communicaton

How would you describe the color of this rose? Would you say it's yellow, sort of le maybe a bright canary yellow?

Your perception and interpretation of color are highly subjective. Eye fatigue, age physiological factors can influence your color perception.

But even without such physical considerations, each observer interprets color bas references. Each person also verbally defines an object's color differently.

As a result, objectively communicating a particular color to someone without some standard is difficult. There also must be a way to compare one color to the next wi

The solution is a measuring instrument that explicitly identifies a color. That is, an that differentiates a color from all others and assigns it a numeric value.

Ways to Measure Color

Today, the most commonly used instruments for measuring color are spectrophot Spectro technology measures reflected or transmitted light at many points on the spectrum, which results in a curve. Since the curve of each color is as unique as a fingerprint, the curve is an excellent tool for identifying, specifying and matching co

The instrumentation and communication of color data is as important as the color Throughout the supply chain, different suppliers may use different processes and color formulation and quality assurance, making compatibility an essential compon products are designed for integration and compatibility throughout the supply chai example, a large installation may use integrated, networked color formulation and assurance software, such as the Color(r) Master and several sphere instruments t shop. A small supplier with a QA-Master I installed on a single computer and one spectrophotometer will be compatible with the larger installation.

The following offers an understanding of which instrument is the best choice for sp applications.

Spherical

Spherically based instruments have played a major roll in formulation systems for years. Most are capable of including the "specular component" (gloss) while meas opening a small trap door in the sphere, the specular component is excluded from measurement. In most cases, databases for color formulation are more accurate w

component is a part of the measurement. Spherical instruments are also the instru choice when the sample is textured, rough, or irregular or approaches the brillianc surface mirror. Textile manufacturers, makers of roofing tiles or acoustic ceiling m all likely select spheres as the right tool for the job.

0/45 (or 45/0)

No instrument "sees" color more like the human eye than the 0/45. This simply is viewer does everything in his or her power to exclude the specular component (glo judging color. When we look at pictures in a glossy magazine, we arrange ourselv gloss does not reflect back to the eye. A 0/45 instrument, more effectively than an remove gloss from the measurement and measure the appearance of the sample human eye would see it.

Multi-Angle

In the past 10 or so years, carmakers have experimented with special effect colors such as mica, pearlescent materials, ground up seashells, microscopically coated pigments and interference pigments are used to produce different colors at differe view. Large and expensive goniometers were traditionally used to measure these battery-powered, hand-held, multi-angle instrument was introduced. X-Rite portab instruments are used by most automakers and their colorant supply chain worldwi

Colorimeter

Colorimeters are not spectrophotometers. Colorimeters are tristimulus (three-filter that make use of red, green and blue filters that emulate the response of the huma and color. In some quality-control applications, these tools can be the least expen Colorimeters cannot compensate for metamerism (a shift in the appearance of a s the light used to illuminate the surface). As colorimeters use a single type of light (incandescent or pulsed xenon) and because they do not record the spectral reflec media, they cannot predict this shift. Spectrophotometers can compensate for this them a better choice for accurate, repeatable color measurement.

Attributes of Color

Each color has its own distinct appearance, based on three elements: hue, chrom (lightness). By describing a color using these three attributes, you can accurately particular color and distinguish it from any other.

Hue

When asked to identify the color of an object, you'll most likely speak first of its hue. Quite simply, hue is how we perceive an object's color - red, orange, green, blue, etc. The color wheel in Figure 1 shows the continuum of color from one hue to the next. As the wheel illustrates, if you were to mix blue and green paints, you would get blue-green. Add yellow to green for yellow-green, and so on.

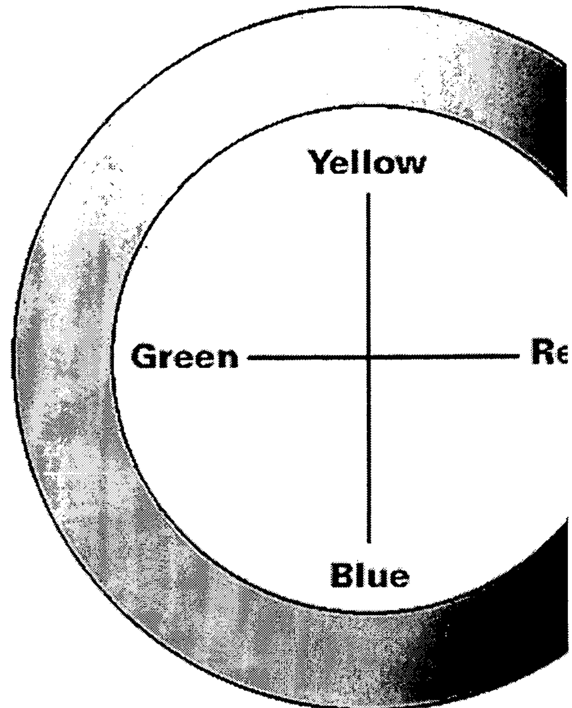

Figure 1 / Hue

Chroma

Chroma describes the vividness or dullness of a color - in other words, how close the color is to either gray or the pure hue. For example, think of the appearance of a tomato and a radish. The red of the tomato is vivid, while the radish appears duller.

Figure 2 shows how chroma changes as we move from center to the perimeter. Colors in the center are gray (dull) and become more saturated (vivid) as they move toward the perimeter. Chroma also is known as saturation.

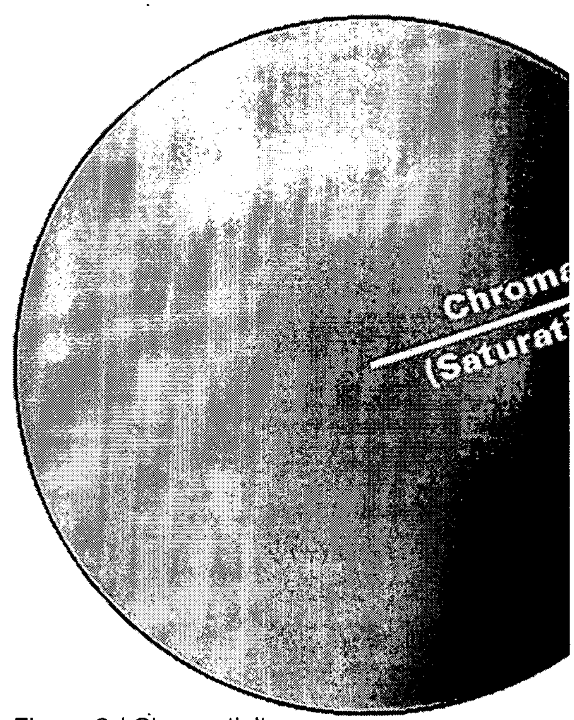

Figure 2 / Chromaticity

Lightness

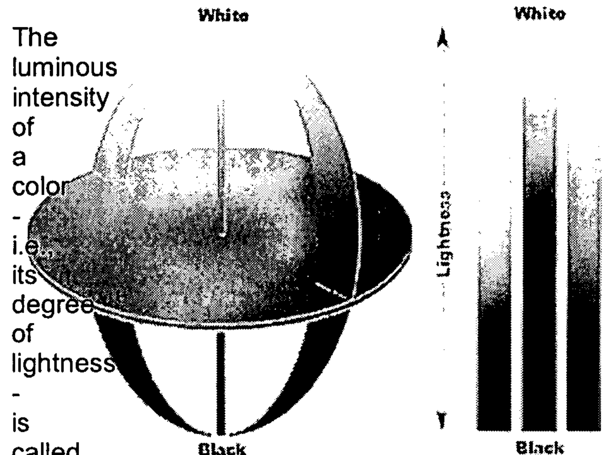

Figure 3 / Three-Dimensional Color System Depicting Lightness

The luminous intensity of a color - i.e., its degree of lightness - is called its value. Colors can be classified as light or dark when comparing their value.

For example, when a tomato and a radish are placed side by side, the red of the t to be much lighter. In contrast, the radish has a darker red value. In Figure 3, the v lightness, characteristic is represented on the vertical axis.

Scales for Measuring Color
The Munsell Scale

In 1905, artist Albert H. Munsell originated a color ordering system - or color scale - that is still used today. The Munsell System of Color Notation is significant from a historical perspective because it's based on human perception. Moreover, it was devised before instrumentation was available for measuring and specifying color. The Munsell System assigns numerical values to the three properties of color: hue, value and chroma. Adjacent color samples represent equal intervals of visual perception.

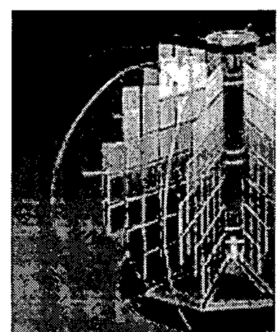

Figure 4 / Munsell Colo

Figure 4 depicts the Munsell Color Tree, which provides physical samples for judging visual color. Today's color systems rely on instrumen mathematics to help us judge color.

Three things are necessary to see color: a light source (illuminant), an object (sam observer/processor.

As humans, we see color because our eyes process the interaction of light hitting What if we replace our eyes with an instrument - can it see and record the same c differences that our eyes detect?

CIE Color Systems

The CIE, or Commission Internationale de l'Eclairage (translated as the International Commission on Illumination), is the body responsible for international recommendations for photometry and

colorimetry. In 1931 the CIE standardized color order systems by specifying the light source (or illuminants), the observer and the methodology used to derive values for describing color.

The CIE Color Systems use three coordinates to locate a color in a color space. These color spaces include CIE XYZ, CIE L*a*b* and CIE L*C*h?. To obtain these values, we must understand how they are calculated.

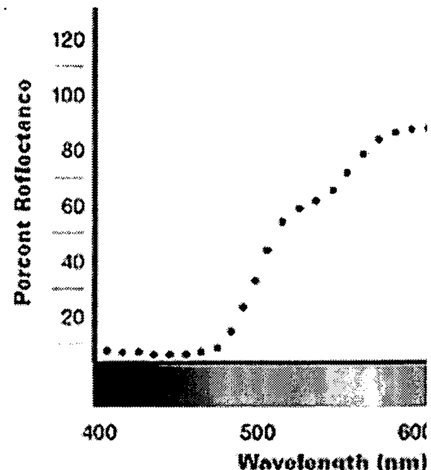

Figure 5 / Spectral Curve from a Me Sample

As stated, our eyes need three things to see color: a light source, an object and an observer/processor. The same must be true for instruments to see color. Color measurement instruments receive color the same way our eyes do - by gathering and filtering the wavelengths of light reflected from an object. The instrument perceive light wavelengths as numeric values. These values are recorded as points across spectrum and are called spectral data. Spectral data is represented as a spectral curve is the color's fingerprint (see Figure 5).

Once we obtain a color's reflectance curve, we can apply mathematics to map the color space. To do this, we take the reflectance curve and multiply the data by a C illuminant. The illuminant is a graphical representation of the light source under wh samples are viewed. Each light source has a power distribution that affects how w Examples of different illuminants are A - incandescent, D65 - daylight (see Figure fluorescent.

We multiply the result of this calculation by the CIE standard observer. The CIE co work in 1931 and 1964 to derive the concept of a standard observer, which is bas average human response to wavelengths of light (see Figure 7).

In short, the standard observer represents how an average person sees color acro spectrum. Once these values are calculated, we convert the data into the tristimul XYZ (see Figure 8). These values can now identify a color numerically.

Chromaticity Values

Tristimulus values, unfortunately, have limited use as color specifications because they correlate poorly with visual attributes. While Y relates to value (lightness), X and Z do not correlate to hue and chroma.

As a result, when the 1931 CIE standard observer was established, the commission recommended using the chromaticity coordinates xyz. These coordinates are used to form the chromaticity diagram in Figure 9. The notation Yxy specifies colors by identifying value (Y) and the color as viewed in the chromaticity diagram (x,y).

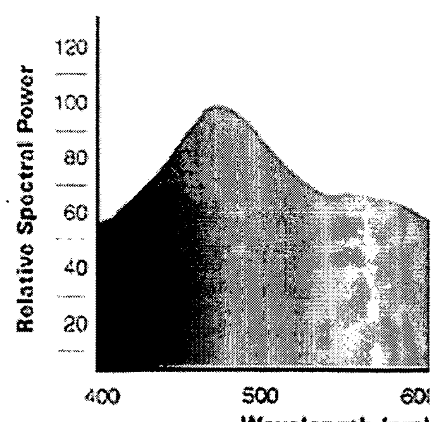

Figure 6 / Daylight (Standard Illumin D65/10_)

As Figure 10 shows, hue is represented at all points around the perimeter of the chromaticity diagram. Chroma, or saturation

represented by a movement from the central white (neutral) area out toward the d perimeter, where 100% saturation equals pure hue.

Expressing Colors Numerically

To overcome the limitations of chromaticity diagrams like Yxy, the CIE recommended two alternate, uniform color scales: CIE 1976 (L*a*b*) or CIELAB, and CIELCH (L*C*h?).

These color scales are based on the opponent-colors theory of color vision, which says that two colors cannot be both green and red at the same time, nor blue and yellow at the same time. As a result, single values can be used to describe the red/green and the yellow/blue attributes.

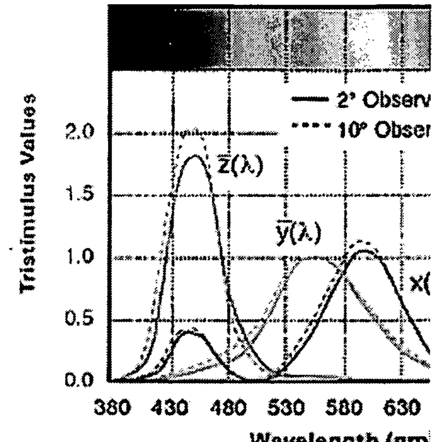

Figure 7 / CIE 2?and 10?Standard

CIELAB (L*a*b*)

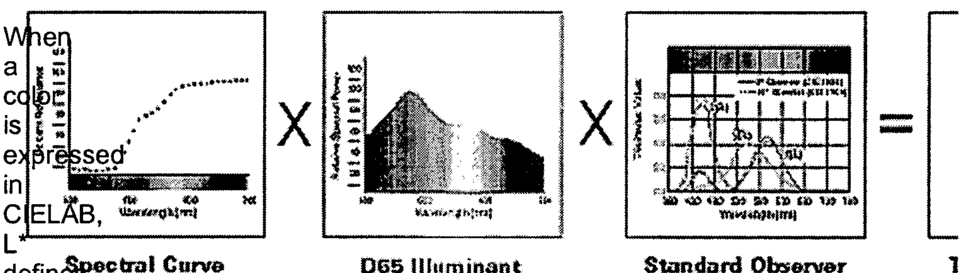

Figure 8 / Tristimulus Values

When a color is expressed in CIELAB, L* defines lightness, a* denotes the red/green value and b* the yellow/blue value.

Figures 11-12 show the color-plotting diagrams for L*a*b*. The a* axis runs from l measurement movement in the +a direction depicts a shift toward red. Along the b movement represents a shift toward yellow. The center L* axis shows L = 0 (black absorption) at the bottom. At the center of this plane is neutral or gray.

To demonstrate how the L*a*b* values represent the specific colors of Flowers A a have been plotted on the CIELAB Color Chart in Figure 11. A and B intersect at co identified respectively as points A and B. These points specify each flower's hue ((vividness/dullness). When their L* values (degree of lightness) are added in Figu color of each flower is obtained.

Color Differences, Notation and Tolerancing Delta CIELAB

Assessment of color is more than a numeric expression. Usually it's an assessment of the color difference (delta) from a known standard. CIELAB is used to compare the colors of two objects. The expressions for these color differences are DL* Da* Db* or DL* Da* Db* (D or D symbolizes "delta," which indicates

difference).

Given DL* Da* Db*, the total difference or distance on the CIELAB diagram can be stated as a single value, known as DE*.

E*ab = [(DL2) + (Da2) + (Db2)]1/2

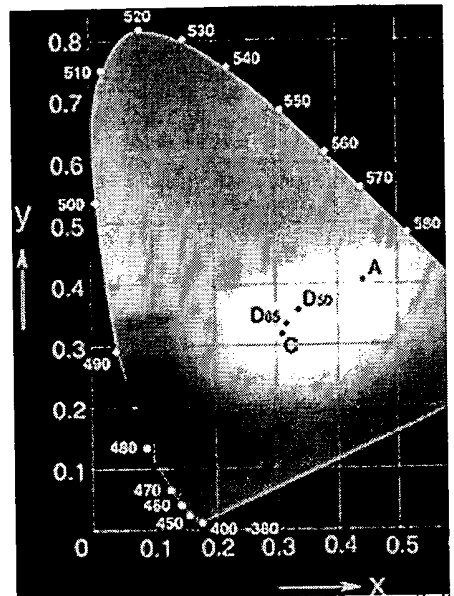

Figure 9 / CIE 1931 (x, y) Chromaticit

CIE Color Space Notation

DL* = difference in lightness/darkness value + = lighter - = darker

Da* = difference on red/green axis + = redder - = greener

Db* = difference on yellow/blue axis + = yellower - = bluer

DE* = total color difference value

Refer to Figure 11.

For more information on color, contact X Rite, phone 800/248.9748; fax 616/534.8960; visit www.x-rite.com; or e-mail info@x-rite.com

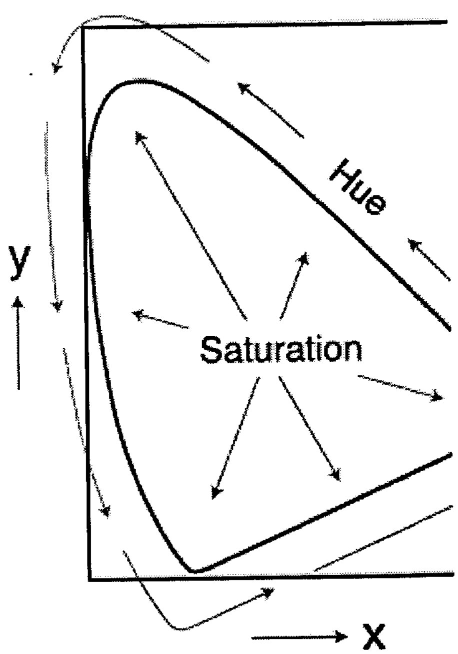

Figure 10 / Chromaticity Diagram

Applications

Spectrophotometry's applications are seemingly boundless. Color-matching measurements are made every day by those comparing a reproduced object to a reference point.

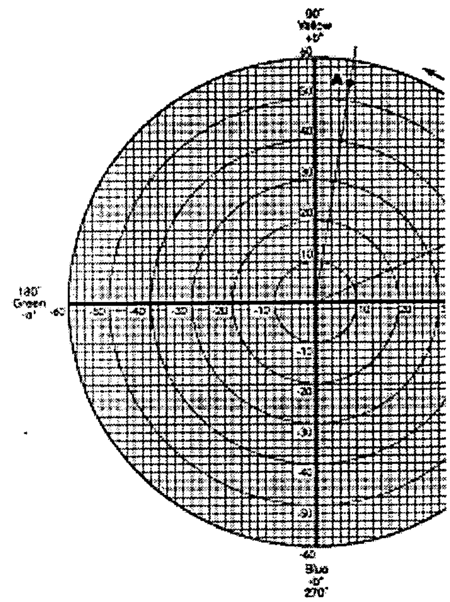

Figure 11 / CIELAB Color Chart

Spectrophotometry-assisted color measurement can be useful in areas including the following.

- Corporate logo standardization
- Color testing of inks
- Color control of paints
- Control of printed colors on packaging material and labels
- Color control of plastics and textiles throughout the development and manufacturing process
- Finished products like printed cans, clothing, shoes, automobile components, plastic components of all types.

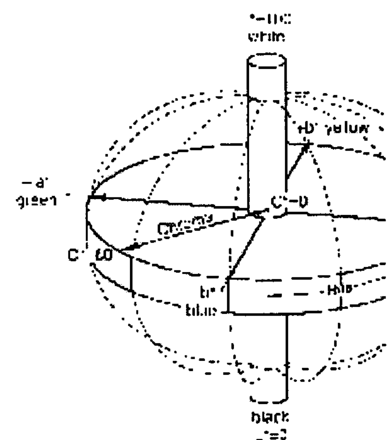

Figure 12 / The L* value is represen center axis. The a* and b* axes app horizontal plane.

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